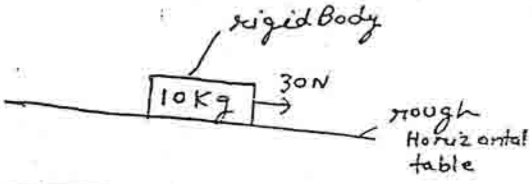
WORK

27th Sep,

Prob 3.1



Given

$m = 10\,Kg$

$F = 30\,N$

displacement $= 1.5\,m$

$\therefore$ Work is done by the agent

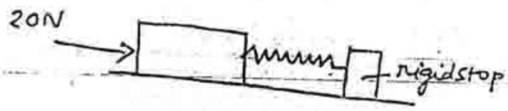
$= F * \text{displacement}$

$= 30 \times 1.5\ N\text{-}m$

$= 45\ N\text{-}m$

$$\boxed{W_d = 45\ N\text{-}m}$$

Prob 3.2



A force of 4N causes spring to compress 10 mm

$\therefore$ K, spring stiffness $= \dfrac{4}{10 \times 10^{-3}}\ N/m$

$\Rightarrow\ K = 4 \times 10^{2}\ N/m$

(a) Work done by the agent

W_{d_1} = displacement work + spring work

$= 20 \times 0.15 + \frac{1}{2} K x^2$

(Here $x = \frac{10}{4} \times 20$)

(x, compression = 150 mm)

$W_{d_1} = 20 \times 0.15 + \frac{1}{2} \times 4 \times 10^2 \times \left(\frac{50}{10^3}\right)^2$ N-m

$W_{d_1} = (3 + 0.5)$ N-m

$W_{d_1} = 3.5$ N-m

$\boxed{W_{d_1} = 3.5 \text{ N-m}}$ Answer

(b) Work done by the agent (altogether)

$W_{d_2} = -\frac{1}{2} K x^2 + W_{d_1}$

$= -\frac{1}{2} \times 4 \times 10^2 \times (50 \times 10^{-3})^2$ N-m $+ 3.5$ N-m

$= (3.5 - 0.5)$ N-m

$= 3$ N-m   180 N-m

$\boxed{W_{d_2} = 3 \text{ N-m}}$ Answer

(c) Work done by the spring in (a)

$W_d = -0.5$ N-m

-180 N-m

Work done by spring in (a) + (b)

$W_d = (-0.5 + 0.5)$ N-m

$= 0$ N-m

$\boxed{W_d = 0 \text{ N-m}}$ Answer

Prob 3.3 Given:- In a particular test, a load of 10^5 N causes a deflection of 0.2 mm at its point of deflection

$\because F \propto x$

$\boxed{F = Kx}$

We know that

$W_d = \frac{1}{2} F x$

$= \frac{1}{2} \times 10^5 \times 0.2 \times 10^{-3}$ N-m

$= 10$ N-m

$\boxed{W_d = 10 \text{ N-m}}$ Answer

Prob 3.4 (a) Work done by agent

$= 5 \times 9.81 \times 10$ N-m

$= 98.1 \times 5$ N-m

$= 490.5$ N-m   Answer

Work done by body $= -490.5$ N-m
Answer

(b) Work done by body

$= +10 \times 30 \times 6$ N-m

$= 1800$ N-m Answer

Work done by the crane

$= -1800$ N-m Answer

(c) Work done by the body

$= +4 \times 30$ (drag Force × dis)

$= 120$ N-m

Work done by the atmosphere

$= -120$ N-m

(d) Work done by the body

$= 0$ N-m bcoz drag force is zero

(just like Free expansion or unresisted expansion of gas)

(e) Work done by the rod

$= 0$ N-m

Prob 3.5

Given :-

$I = 14$

$V = 200$ volts

$T = 15$ sec

$m = 2$ tonne
$= 2000$ kg

vertical distance $= 2$ m

Work done by electric motor

$= -VIT$

$= -200 \times 14 \times 15$ Joules

$= -42000$ J

$\boxed{-42000 J}$ Answer

2760 N-m

Work done by machine

$= -2000 \times 9.81 \times 2$ N-m

$= -39.24 \times 10^3$ N-m

$= -39240$ N-m

$\boxed{-39240 \text{ N-m}}$ Answer

Work done by inextensible cable

$= 0$

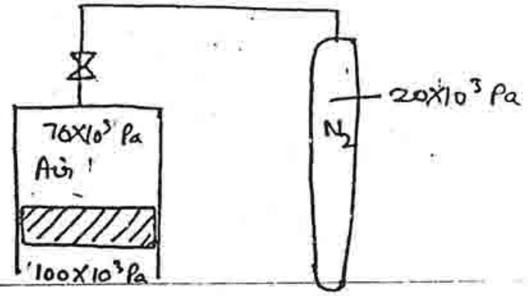
Work done by pulley

$= 0$

Prob 3.6

M. Imp

(a) Work done by the piston



$= -(100-70)\times10^3 \times V_{sw}$

$= -30\times10^3 \times \underline{20\times10^{-4}\times 0.1}$ N-m

$= -6$ J — ∵ (work is done by the atm on the piston)

$\boxed{-6 \text{ N-m}}$ Answer

(b) Workdone by the atmosphere pV_{sw} $\vec{=}$ A × length

$= 100\times10^3 \times 20\times10^{-4}\times0.1$ N-m

$= 20$ N-m

$\boxed{+20 \text{ N-m}}$ Answer

(c) Workdone by (air + N_2)

$=$ Workdone by air + Workdone by N_2

$= -70\times10^3\times V_{sw} + 0$

$= -70\times10^3 \times 20\times10^{-4}\times0.1$ N-m

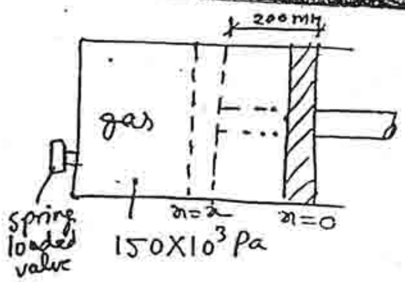
$= -14$ N-m

$\boxed{-14 \text{ N-m}}$ Answer

Prob 3.7

Let

$p = ax + b$ —(1)



at $x=0$, $p = 150\times10^3$ N/m²

$\boxed{b = 150\times10^3 \text{ N/m}^2}$

Now at $x = 200$ mm, $p = 300\times10^3$ N/m²

$300\times10^3 = a\times0.2 + 150\times10^3$

$\boxed{a = 75\times10^4 \text{ N/m}^2}$

$W = \int_0^{0.2} p\,dV$ 200 mm

$= \int_0^{0.2} (ax+b)A\,dx$

$= \left[\frac{aAx^2}{2} + Abx\right]_0^{0.2}$

$= 220\times10^{-4}\left[\frac{75\times10^4\times0.04}{2} + 150\times10^3\times0.2\right]$

$= 990$ N-m

b) Since the swept volume remains same (∵ Area is same and distance moved by the piston is same) Hence work done will be same as in part (a)

$\boxed{990,\ 990 \text{ N-m}}$ Answer

Work done per cycle

$W_d = p_m \cdot V_{sw}$ $\quad A = \pi \left(\frac{20\,mm}{4}\right)^2$

$W_d = \left(\frac{aS}{l}\right) \cdot LA \quad L = 250\,m.$

$W_d = 900 \times 0.0314 \times 0.250$ N-m

$= 7.065$ N-m $\quad W_d = 7060.5\,N$

Indicated Power

Indicated power (For double acting 2-stroke engine) $= 2\,\underbrace{p_m \times LA}_{W_d}\,N$

$= 2 \times 7.065 \times \frac{300}{60}$ KW

$= 70.65$ KW

Answer $\boxed{\begin{array}{l} 7.065 \text{ KN-m} \\ 70.65 \text{ KW} \end{array}}$

Given

Axial Force $= 60$ N

Length of stylus moved $= 10$

Area of piston (moved) $A_i = 4\,cm^2$
$= 4 \times 10^{-4}\,m^2$

(a) Spring Number

Spring number $= \frac{\text{change in steam pressure}}{\text{length of stylus moved}}$

$= \frac{\text{Force}}{\text{Area} \times \text{length of stylus moved}}$

$= \frac{60}{4 \times 10^{-4} \times 6 \times 10^{-3}}$

$= 25 \times 10^6 \times 10$ N/m^3

$= 25 \times 10^6$ N/m^3

$\boxed{25 \times 10^6\, N/m^3}$

(b) Area of indicator diagram

Area of piston $= \frac{\pi d^2}{4} = \frac{\pi \times 150^2 \times 10^{-6}}{4}$

$= \frac{\pi}{4} \times (150 \times 10^{-3})^2\; m^2$

Indicated power $= 4.5$ KW

$N = 216$ rpm

$N = \frac{216}{60}$ rps $\Rightarrow \frac{7.2}{2}$ rps

$l = 0.1L$

$4.5\times10^3 = \frac{aS}{l}\cdot LA\frac{N}{2}$ Prob 3.11

$4.5\times10^3 = \frac{a\times25\times10^6\times L\times\pi\times(150\times10^{-3})^2\times7.2}{0.1L\times4\times2\times2}$

$4.5K = \frac{a\times25\times10^6}{0.1L}\times L\times\frac{\pi\times(150\times10^{-3})^2}{4}\times\frac{216}{60\times2}$

$= 565.88\times10^{-6}$

$a = 566\ mm^2$

$\boxed{a = 566\ mm^2}$ Answer

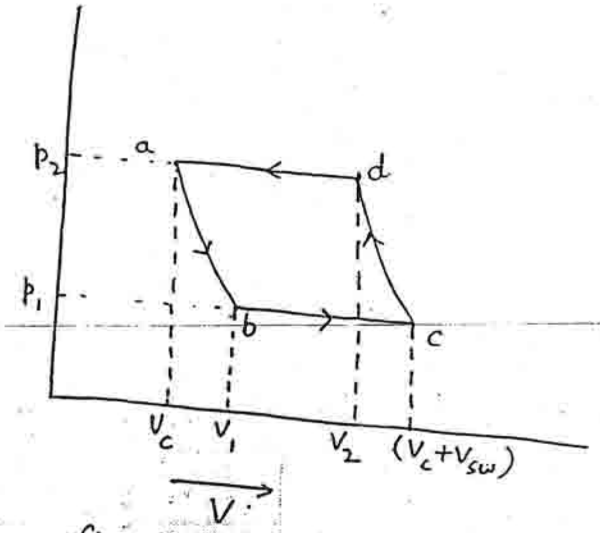
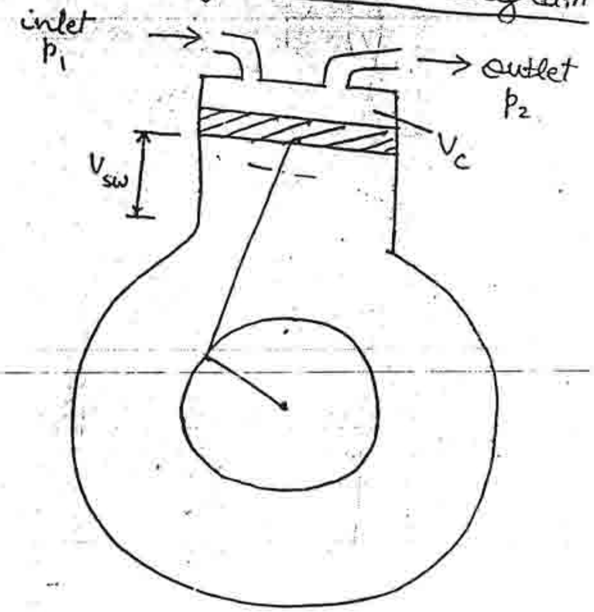


fig: Indicator Diagram



Prob 3.10

Given

no. of cylinders, $k = 6$

Speed $= 2520\ rpm$

$N = \frac{2520}{60}\ rps$

$N = 42\ rps$

$a = 2.33\times10^3\ mm^2$

$l = 62.1\ mm$

$S = 20\times10^6\ N/m^3$

$A = \frac{\pi}{4}\times(150)^2\times10^{-6}\ m^2 \Rightarrow 0.0177\ m^2$

$L = 160\ mm$

Indicated power $= k\left(\frac{aS}{l}\right)\cdot LA\frac{N}{2}$

$= \frac{42\times6\times2.33\times10^3\times10^{-6}\times20\times10^6\times160\times10^{-3}\times0.0177}{2\times62.1\times10^{-3}}$

$= 267.77\ KW$

$\boxed{267.77\ KW}$ Ans

Let p_1 be the inlet pressure and p_2 be the delivery pressure of air.

$$\left(\because V_c = \frac{c}{100} V_{sw} \right)$$

Where V_c is the clearance volume.
V_{sw} is the swept volume.

a (p_2, V_c)
b (p_1, V_1)
c $(p_1, \{V_c + V_{sw}\})$
d (p_2, V_2)

For (a-b)

$$p_2 V_c^n = p_1 V_1^n$$

$$V_1 = \left(\frac{p_2}{p_1}\right)^{1/n} \cdot V_c$$

$$\boxed{V_1 = \left(\frac{p_2}{p_1}\right)^{1/n} \cdot \frac{c V_{sw}}{100}}$$

For (b-c)

at b $\rightarrow V_1$

at c $\rightarrow (V_c + V_{sw})$

For (c-d)

$$p_1 (V_c + V_{sw})^n = p_2 V_2^n$$

$$V_2 = \left(\frac{p_1}{p_2}\right)^{1/n} \left(\frac{c V_{sw}}{100} + V_{sw} \right)$$

$$\boxed{V_2 = \left(\frac{p_1}{p_2}\right)^{1/n} \cdot \left(1 + \frac{c}{100}\right) \cdot V_{sw}}$$

For (d-a)

at d $\rightarrow V_2$

at a $\rightarrow V_c$

Net work done at the piston face per cycle is given by

$$W = \oint p \, dv$$

$$W = \int_a^b p\,dv + \int_b^c p\,dv + \int_c^d p\,dv + \int_d^a p\,dv$$

$$W = \frac{p_1 V_1 - p_2 V_c}{1-n} + p_1 (V_c + V_{sw} - V_1)$$

$$+ \frac{p_2 V_2 - p_1 (V_c + V_{sw})}{1-n} + p_2 (V_c - V_2) \qquad \text{—— (1)}$$

$$\int_a p\,dv = \frac{p_1 V_1 - p_2 V_c}{1-n}$$

$$= \frac{p_1 \left(\frac{p_2}{p_1}\right)^{1/n} \frac{c V_{sw}}{100} - p_2 \frac{c}{100} V_{sw}}{1-n}$$

$$= \frac{V_{sw} \cdot p_1}{n-1} \left[\left(\frac{p_2}{p_1}\right) \frac{c}{100} - \left(\frac{p_2}{p_1}\right)^{1/n} \frac{c}{100} \right]$$

$$\int_b^c p\,dv = p_1 (V_c + V_{sw} - V_1)$$

$$= p_1 \left(\frac{c}{100} \cdot V_{sw} + V_{sw} - \left(\frac{p_2}{p_1}\right)^{1/n} \frac{c \cdot V_{sw}}{100} \right]$$

$$= \frac{V_{sw} \cdot p_1}{n-1} \left[\frac{c}{100} + 1 - \left(\frac{p_2}{p_1}\right)^{1/n} \frac{c}{100} \right] (n-1)$$

$$= \frac{V_{sw} * p_1}{n-1} \left[\frac{nc}{100} + n - n \left(\frac{p_2}{p_1}\right)^{1/n} \frac{c}{100} - \frac{c}{100} - 1 + \left(\frac{p_2}{p_1}\right)^{1/n} \frac{c}{100} \right]$$

$$\int_c^d p\,dv = \frac{p_2 V_2 - p_1 (V_c + V_{sw})}{1-n}$$

$$= \frac{p_2 \left(\frac{p_1}{p_2}\right)^{1/n} \left(1 + \frac{c}{100}\right) V_{sw} - p_1 \left\{ \frac{c}{100} \cdot V_{sw} + V_{sw} \right\}}{1-n}$$

$$= \frac{V_{sw} \cdot p_1}{n-1} \left[\frac{c}{100} + 1 - \left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} \left(1 + \frac{c}{100}\right) \right]$$

$$= \frac{V_{sw} \cdot p_1}{n-1} \left[\frac{c}{100} + 1 - \left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} - \left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} \frac{c}{100} \right]$$

$$\int_d^a p\,dv = -p_2 (V_2 - V_c)$$

$$= -p_2 \left[\left(\frac{p_1}{p_2}\right)^{1/n} \left(1 + \frac{c}{100}\right) V_{sw} - \frac{c}{100} V_{sw} \right]$$

$$= \frac{-p_1 \cdot V_{sw}}{n-1} \left[\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} \left(1 + \frac{c}{100}\right) - \left(\frac{p_2}{p_1}\right) \frac{c}{100} \right] (n-1)$$

$$= \frac{-p_1 \cdot V_{sw}}{n-1} \left[n \left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} \left(1 + \frac{c}{100}\right) - \frac{nc}{100} \left(\frac{p_2}{p_1}\right) - \left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} \left(1 + \frac{c}{100}\right) + \left(\frac{p_2}{p_1}\right) \frac{c}{100} \right]$$

$$\int_d p\,dv = -\frac{p_1 \cdot V_{sw}}{n-1}\left[n\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} + \frac{nc}{100}\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} - \frac{nc}{100}\left(\frac{p_2}{p_1}\right) - \left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} - \left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}\frac{c}{100} + \left(\frac{p_2}{p_1}\right)\frac{c}{100} \right]$$

Now from eq (1)

$$W = \frac{V_{sw}\cdot p_1}{(n-1)}\left[\cancel{\left(\frac{p_2}{p_1}\right)\frac{c}{100}} - \cancel{\left(\frac{p_2}{p_1}\right)^{1/n}\frac{c}{100}} + \frac{nc}{100} + n - n\left(\frac{p_2}{p_1}\right)^{1/n}\frac{c}{100} - \cancel{\frac{c}{100}} \cancel{- 1 + \frac{c}{100}\left(\frac{p_2}{p_1}\right)^{1/n}} + \cancel{\frac{c}{100}} + \cancel{1} - \cancel{\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}} - \cancel{\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}\frac{c}{100}} - n\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} - \frac{nc}{100}\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} + \frac{nc}{100}\left(\frac{p_2}{p_1}\right) + \cancel{\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}} + \cancel{\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}\frac{c}{100}} - \cancel{\left(\frac{p_2}{p_1}\right)\frac{c}{100}} \right]$$

$$\therefore W = \frac{p_1 \cdot V_{sw}}{n-1}\left[\frac{nc}{100} + n - \frac{nc}{100}\left(\frac{p_2}{p_1}\right)^{1/n} - n\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} - \frac{nc}{100}\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} + \frac{nc}{100}\left(\frac{p_2}{p_1}\right) \right]$$

$$W = \frac{p_1 \cdot V_{sw}}{n-1}\left[n - \frac{nc}{100}\left(\frac{p_2}{p_1}\right)^{1/n} + \frac{nc}{100} - n\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} + \frac{nc}{100}\left(\frac{p_2}{p_1}\right) - \frac{nc}{100}\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \right]$$

$$W = \frac{n}{n-1}\cdot p_1 \cdot V_{sw}\left[1 - \frac{c}{100}\left\{\left(\frac{p_2}{p_1}\right)^{1/n} - 1\right\} - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\left\{ 1 - \frac{c}{100}\left\{\left(\frac{p_2}{p_1}\right)^{1/n} - 1\right\}\right\} \right]$$

$$W = \frac{n}{n-1}\cdot p_1 \cdot V_{sw}\left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]\cdot\left[1 - \frac{c}{100}\left\{\left(\frac{p_2}{p_1}\right)^{1/n} - 1\right\}\right]$$

$$\boxed{W = \frac{n}{n-1}\cdot p_1 \cdot V_{sw}\left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]\left[1 - \frac{c}{100}\left\{\left(\frac{p_2}{p_1}\right)^{1/n} - 1\right\}\right]}$$

Answer

$$\int_d p\,dv = -\frac{p_1 \cdot V_{sw}}{n-1}\left[n\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} + \frac{nc}{100}\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} - \frac{nc}{100}\left(\frac{p_2}{p_1}\right) - \left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} - \left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}\frac{c}{100} + \left(\frac{p_2}{p_1}\right)\frac{c}{100} \right]$$

Now from eq (1)

$$W = \frac{V_{sw} \cdot p_1}{(n-1)}\left[\cancel{\left(\frac{p_2}{p_1}\right)\frac{c}{100}} - \cancel{\left(\frac{p_2}{p_1}\right)^{1/n}\frac{c}{100}} + \frac{nc}{100} + n - n\left(\frac{p_2}{p_1}\right)^{1/n}\frac{c}{100} - \cancel{\frac{c}{100}} - \cancel{1} + \cancel{\frac{c}{100}\left(\frac{p_2}{p_1}\right)^{1/n}} \right.$$

$$\left. + \cancel{\frac{c}{100}} + \cancel{1} - \cancel{\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}} - \cancel{\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}\frac{c}{100}} - n\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} - \frac{nc}{100}\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} + \frac{nc}{100}\left(\frac{p_2}{p_1}\right) + \cancel{\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}} + \cancel{\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}}\frac{c}{100}} - \cancel{\left(\frac{p_2}{p_1}\right)\frac{c}{100}} \right]$$

$$\therefore W = \frac{p_1 \cdot V_{sw}}{n-1}\left[\frac{nc}{100} + n - \frac{nc}{100}\left(\frac{p_2}{p_1}\right)^{1/n} - n\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} - \frac{nc}{100}\left(\frac{p_1}{p_2}\right)^{\frac{1-n}{n}} + \frac{nc}{100}\left(\frac{p_2}{p_1}\right) \right]$$

$$W = \frac{p_1 \cdot V_{sw}}{n-1}\left[n - \frac{nc}{100}\left(\frac{p_2}{p_1}\right)^{1/n} + \frac{nc}{100} - n\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} + \frac{nc}{100}\left(\frac{p_2}{p_1}\right) - \frac{nc}{100}\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \right]$$

$$W = \frac{n}{n-1} \cdot p_1 \cdot V_{sw}\left[1 - \frac{c}{100}\left\{\left(\frac{p_2}{p_1}\right)^{1/n} - 1\right\} - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\left\{ 1 - \frac{c}{100}\left\{\left(\frac{p_2}{p_1}\right)^{1/n} - 1\right\}\right\} \right]$$

$$W = \frac{n}{n-1} \cdot p_1 \cdot V_{sw}\left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right] \cdot \left[1 - \frac{c}{100}\left\{\left(\frac{p_2}{p_1}\right)^{1/n} - 1\right\}\right]$$

$$\boxed{W = \frac{n}{n-1} \cdot p_1 \cdot V_{sw}\left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]\left[1 - \frac{c}{100}\left\{\left(\frac{p_2}{p_1}\right)^{1/n} - 1\right\}\right]}$$

Answer

$p_1 = 100 \times 10^3 \ N/m^2$

$V_{sw} = 2.4 \ dm^3$

$c = 5\%$ and $n = 1.2$

$W = -415$ N-m/cycle

$\boxed{W = -415 \text{ N-m/cycle}}$ Answer

1 (iv) Indicated power

$= W \times \frac{n}{60}$ ($n = 390$ rpm)

$= W \times N$ (N = rps)

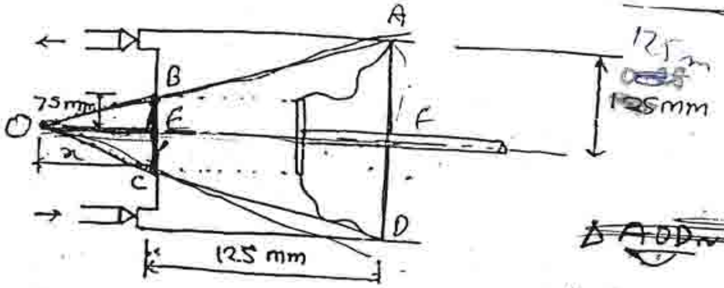
$= W \times \frac{390}{60}$

$= -415 \times \frac{390}{60}$ W

$= -2.7$ KW

$\boxed{\text{Indicated Power} = -2.7 \text{KW}}$

Answer



$\Delta AOD \sim \Delta BOE$

Now, using similar triangle

$\frac{x}{125+x} = \frac{75}{125}$

$125x = 125 \times 75 + 75x$

$x = 187.5$ mm

Swept volume = 2X volume of frustum of cone ABCD

$= 2 \times \frac{\pi}{3} \left(125^2 \{187.5 + 125\} - 75^2 \times 187.5 \right)$

$= \frac{2 \times 3.14}{3} \left[3.828 \times 10^6 \right]$

$= 8.02 \times 10^6 \ mm^3$

$= 8.02 \times 10^{-3} \ m^3$

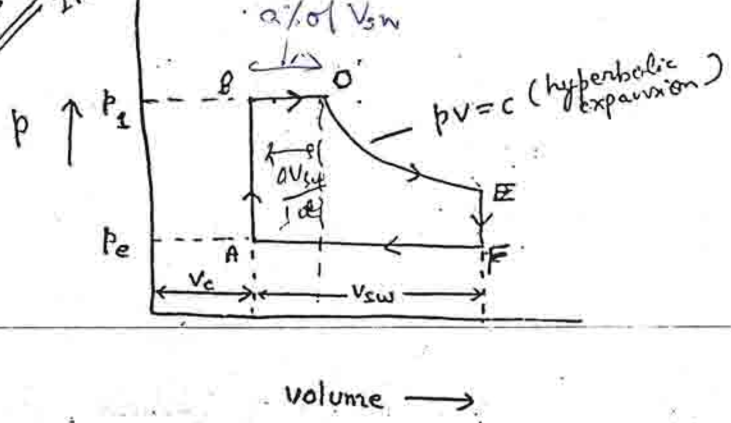
$\therefore W = p * V_{sw}$

$= 180 \times 10^3 \times 8.02 \times 10^{-3}$ N-m

$= 1443.7$ N-m

$\boxed{W = 1443.7 \text{ N-m}}$ Answer

Prob 3.13 IMP



Net work done at piston face per cycle

$$W = \oint p\,dv$$

$$W = \int_A^B p\,dv + \int_B^D p\,dv + \int_D^E p\,dv + \int_E^F p\,dv + \int_F^A p\,dv$$

$$W = 0 + p_1(V_D - V_B) + p_1 V_D \ln\left(\frac{V_E}{V_D}\right) + 0 + p_e(V_A - V_F)$$

$$W = p_1(V_D - V_B) + (V_A - V_F)p_e + p_1 V_D \ln\left(\frac{V_E}{V_D}\right)$$

$$W = p_1\left(\frac{a V_{sw}}{100}\right) - p_e V_{sw} + p_1\left[V_c + \frac{a V_{sw}}{100}\right] \cdot \ln\left[\frac{V_{sw} + V_c}{\frac{a V_{sw}}{100} + V_c}\right]$$

$$W = \frac{a p_1 \cdot V_{sw}}{100} - p_e V_{sw} + p_1\left[\frac{c V_{sw}}{100} + \frac{a V_{sw}}{100}\right] \cdot \ln\left[\frac{V_{sw} + \frac{c V_{sw}}{100}}{\frac{a V_{sw}}{100} + \frac{c V_{sw}}{100}}\right]$$

$$W = V_{sw}\left[\frac{p_1}{100}\left\{a + (a+c)\ln\frac{100+c}{a+c}\right\} - p_e\right]$$

$$\boxed{W = V_{sw}\left[\frac{p_1}{100}\left\{a + (a+c)\ln\frac{100+c}{a+c}\right\} - p_e\right]}$$

Answer

We Know that

$$W = p_m V_{sw}$$

$$\boxed{p_m = \frac{p_1}{100}\left\{a + (a+c)\ln\frac{100+c}{a+c}\right\} - p_e}$$

Answer

(iii) $p_1 = 550 \times 10^3 \; N/m^2$

$p_e = 100 \times 10^3 \; N/m^2$

$a = 30\%$

$c = 5\%$

$p_m = ?$

$$p_m = 10^3\left[5.5\left\{30 + 35 \ln\frac{105}{35}\right\} - 100\right]$$

$$p_m = 276 \times 10^3 \; N/m^2$$

$$\boxed{p_m = 276 \times 10^3 \ N/m^2}$$ Answer

$W = p_m V_{sw}$

$= 276 \times 10^3 \left[0.28 \times \frac{\pi}{4} (0.230)^2 \right]$

$= 3210.8$ N-m/cycle

$$\boxed{W = 3210.8 \text{ N-m/cycle}}$$ Answer

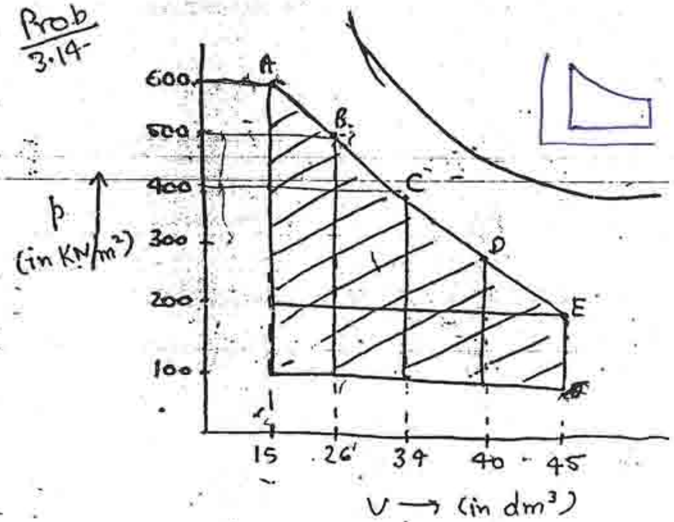
(iv) Indicated power $= 2 \times W \times N$

$= \left(2 \times 3210.8 \times \frac{132}{60}\right)$ W

$= 14.13$ KW

$$\boxed{\text{Indicated Power} = 14.13 \text{ KW}}$$ Answer

Prob 3.14



Workdone by the fluid system

$= 10^3 \left[\frac{(600+500)}{2} \times \cancel{14} \right.$

$+ \frac{(500+400)}{2} \times 8 + \frac{(400+300)}{2} \times 6$

$\left. + \frac{(300+200)}{2} \times 5 \right]$

$= \frac{10^3}{2} [12100 + 4200 + 7200 + 2500]$

$= 13 \times 10^6 \ N/m^2 \times 10^{-3} \ m^3$

$= 13 \times 10^3$ N-m

~~Prob~~ 3.15 The position of the piston when the baloon is fully inflated is given by

$Ax = 0.003$

$x = \frac{0.003}{150 \times 10^{-4}} \Rightarrow 0.2$ m

$x = 200$ mm

Now upto $x = 200$ mm the pressure in the left end remains same as initial i.e 100×10^3 Pa. Now on further movement of the piston, We have to follow $pV =$ constant. Now, when $x = 250$ mm then volume of the left position of the cylinder is given by $(250 - 200 = 50$ mm)

$= 0.0045 - 150 \times 10^{-4} \times 50 \times 10^{-3}$

$= 3.75 \times 10^{-3} \ m^3$

100000

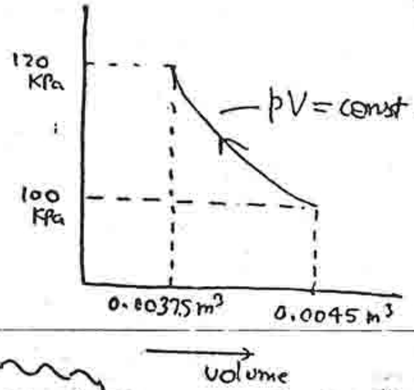
and corresponding pressure is given by

$$p_1 V_1 = p_2 V_2$$

$$p_2 = \frac{p_1 V_1}{V_2}$$

$$p_2 = \frac{100\times10^3 \times 0.0045}{3.75\times10^{-3}}$$

$$p_2 = 120\times10^3\ N/m^2$$



(b)(i) Workdone by atmosphere

$= p_{atm} \cdot V_{sw}$

$= 100\times10^3 (-0.003)$ — ve ∵ of contraction

$= -300\ J$ Answer

(b)(ii) Work done by Baloon

= Work done by Baloon on atmosphere + Work done by Baloon on air

$= 300 - 100\times10^3 \times 0.003$

$= 300 - 300$

$= 0\ J$ Answer

(iii) Workdone by the air

= Workdone by air on Baloon + Workdone by air on piston

$= 100\times10^3 \times 0.003 + \left[-100\times10^3 \times 0.003 - 100\times10^3 \times 0.0045 \ln\left(\frac{.00375}{.0045}\right)\right]$

→ for upto inflation

→ after inflation

$= 300 - 300 - 82$

$= -82\ J$ Answer

(iv) Workdone by the piston

$= 0$ Answer.

Since the piston is freely floating and frictionless leakproof

(V) Workdone by the nitrogen.

= Workdone by piston on air

or

= − Work done by air on piston

$= -\left[-100\times10^3 \times 0.003 - 100\times10^3 \times 0.0045 \ln\left(\frac{0.00375}{0.0045}\right)\right]$

$= -(-300 - 82)\ J$

$= +382\ J$ Answer

Prob 3.16

Volume leaked from the main to the rigid vessel

= (mass decreased) × sp. volume

$= 0.1 \times 0.1520$

$= 0.01520\ m^3$

Workdone $= (-)\, p\, V_{sw}$

$= -1.5 \times 10^6 \times 0.01520\ J$

$= -22.8 \times 10^3\ J$

$\boxed{\text{Workdone} = -22.8\ KJ}$ Answer

Prob 3.17

$p = p_{atm} + \text{hydrostatic pressure}$

$= 100 \times 10^3 + \rho g h$

$= 10^5 + 2.5 \times 1100 \times 9.81$

$= 1.27 \times 10^5\ N/m^2$

change in volume $\Delta V = \frac{4}{3}\pi(r_2^3 - r_1^3)$

$= \frac{4}{3}\pi\left[0.5^3 - 0.25^3\right]$

$= 0.458\ m^3$

$\therefore W = p\,\Delta V$

$= 1.27 \times 10^5 \times 0.458\ J$

$= 58.2\ KJ$

$\boxed{W = 58.2\ KJ}$ Answer

Prob 3.18

$\boxed{\text{Shaft Power} = \text{Torque} \times 2\pi N}$

$= 260 \times 2\pi \times \frac{3000}{60}\ W$

$= 81692\ W$

$= 81.7\ KW$

$\boxed{\text{Shaft Power} = 81.7\ KW}$

Prob 3.19

(a) $W = 2\pi N T$

$15 \times 10^6 = 2 \times \pi \times \frac{1440}{60}\ T$

$T = \frac{15 \times 10^6 \times 60}{2\pi \times 1440}\ N\text{-}m$

$T = 99.5 \times 10^3\ N\text{-}m$

$\boxed{T = 99.5\ KN\text{-}m}$ Answer

(b) Power delivered to the propeller shaft

$P = 2\pi N T$

$P = \frac{2 \times \pi \times 1440 \times 770 \times 10^3}{8 \times 60}\ W$

$P = 14.52\ MW$

$\boxed{P = 14.52\ MW}$ Answer

(c) Net rate of working of the reduction gear

$$= (-15000 + 14520) \times 10^3 \ N\text{-}m/s$$
$$= -480 \times 10^3 \ N\text{-}m/s$$

$\boxed{-480 \times 10^3 \ N\text{-}m/s}$ Answer

Prob 3.20 diameter of cylinder = 400 mm.

Net work done during the process by the fluid = 2000 N-m

$$V_{sw} = \frac{\pi}{4} \times \left(\frac{400}{1000}\right)^2 \times \frac{485}{1000} \ m^3$$

$$V_{sw} = 0.0609 \ m^3$$

Work done by the piston = $p V_{sw}$

$$= 101 \cdot \times 10^3 \times 0.0609 \ N\text{-}m$$
$$= 6169.17 \ N\text{-}m$$

Work done on the fluid = (6169.17 − 2000) N-m

$$= 4169.17 \ N\text{-}m$$

∴ Workdone in one minute by the motor

$$= \frac{4169.17}{10} \ N\text{-}m$$

$$2\pi N T = 4169.17$$

$$T = \frac{4169.17}{2 \times \pi \times 10 \times 840} \ N\text{-}m$$

$$T = 0.079 \ N\text{-}m$$

$\boxed{T = 0.079 \ N\text{-}m}$ Answer

$$\text{Shaft power} = \frac{\text{Workdone in one min}}{60}$$
$$= \frac{4169.17}{60 \times 10} \ W$$
$$= 6.95 \ W$$

$\boxed{\text{Shaft power} = 6.95 \ W}$ Answer

Prob 3.21 (a) Net work done by the accumulator

$$= 24 \times 0.35 \times 10 \times 60$$
$$= 5040 \ N\text{-}m$$

$\boxed{5040 \ N\text{-}m}$ Answer

(b) Net work done by the motor

$$= 4169.17 - 5040$$
$$= -870.83 \ N\text{-}m$$

$\boxed{-870.83 \ N\text{-}m}$ Answer

—— × ch-3 × ——

Examples 3.1, 3.2, 3.3 and 3.4 are prepared also (IMP) (solved in Book)

Chapter-4 28th SEP 2007

Temperature

Prob. 4.1 (a) Given

Temp = 336°C

so $t_F = \frac{9}{5} t_c + 32$

$= \frac{9}{5} \times 336 + 32$

$= 636.8°F$

$\boxed{t_F = 636.8°F}$ Answer

(b) Given temp = 5°F

$t_c = \frac{5}{9}(F-32)$

$= \frac{5}{9}(5-32)$

$= -15°C$

$\boxed{t_c = -15°C}$ Answer

(c) Given temp = -1°

$t_F = 1.8 t_c + 32$

$= (1.8 \times -1 + 32)°F$

$= 30.2°F$

$\boxed{t_F = 30.2°F}$ Answer

(d) Given temp = 1050°F

$t_c = \frac{5}{9}(F-32)$

$t_c = \frac{5}{9}(1050-32) \Rightarrow 565.56°C$

$\boxed{t_c = 565.56°C}$ Answer

(e) $Temp_1 = 68°F$

$t_{c_1} = \frac{5}{9}(68-32) \Rightarrow 20°C$

$Temp_2 = 554°F$

$t_{c_2} = \frac{5}{9}(554-32) \Rightarrow 290°C$

Increase in temp $(\Delta t_c) = (290-20)°C$

$\Delta t_c = 270°C$

$\boxed{\Delta t_c = 270°C}$ Answer

Prob. 4.2 $t = a \ln P + b$

at $t=0$, $P=1.86 \Rightarrow a \ln 1.86 + b = 0$ — (1)

at $t=100$, $P=6.81 \Rightarrow a \ln 6.81 + b = 100$ — (2)

Solving eq (1) and (2) we get.

$a = 76.92$ and $b = -47.57$

Now at $P = 2.5$

$t = 76.92 \ln 2.5 - 47.57$

$= 22.91°C$

$\boxed{t = 22.91°C}$ Answer

Prob 4.3 (a) $t_A = l + m t_B + n t_B^2$

at $t = 0$ $\boxed{l = 0}$ ✓

at $t = 100 = t_A = t_B$

$100 = m(100) + n(100)^2$

$1 = m + 100n$ — ①

at $t_A = 51$ and $t_B = 50$

$51 = 50m + 2500n$ — ②

Multiplying eq ① by 50, then subtract from eq ②, we get $n = \frac{-1}{2500}$

$\Rightarrow 51 = 50m - 1$

$m = \frac{52}{50} = 1.04$

When $t_A = 25°C$ then t_B

$25 = (1.04 t_B) + \left(\frac{-1}{2500}\right) t_B^2$

$62500 = 2600 t_B - t_B^2$

$t_B^2 - 2600 t_B + 62500 = 0$

$t_B = \frac{2600 \pm \sqrt{(-2600)^2 - 4(62500)}}{2}$

$= \frac{2600 \mp 2551.4}{2}$

$t_B = 24.27°C$

$\boxed{t_B = 24.27°C}$ Answer

(b) The two given thermometers are arbitrary. Each step from the selection of the thermometric substance and the earning material to the choice of the no. of equal sub-divisions b/w the fixed points is unrelated. It is upto us which we shall call right one and which wrong. All that is necessary is that we should make a decision and stick to it.

Prob 4.4 (a) $p = 1000[1 + \alpha(t - 0)]$

$1366 = 1000(1 + \alpha t)$

$\alpha = 3.66 \times 10^{-3}$

(b) $\therefore p = 1000(1 + 3.66 \times 10^{-3} t_c)$

$\frac{p}{1000} - 1 = 3.66 \times 10^{-3} t_c$

$t_c = \frac{p}{3.66} - \frac{1}{3.66 \times 10^{-3}}$

$\Rightarrow t_c = 0.273p - 273$

$t = 0.273 \times 1075 - 273$

$= 20.475°C$

$\simeq 20.5°C$

$\boxed{\begin{array}{l}\alpha = 3.66 \times 10^{-3} \\ t \simeq 20.5°C\end{array}}$ Answer

Chapter – 5

Heat

$c = 4200\,J$

Prob 5.1

$1\ J = 0.2388 \times 10^{-3}$ Kilocalories

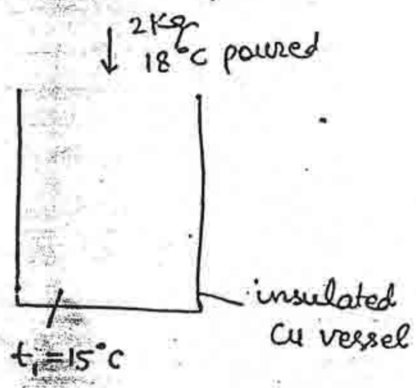
($\because$ 1 Btu = 0.252 Kcal)

$$1\ Btu = \frac{0.252}{0.2388 \times 10^{-3}}\ J$$

$$= 1.055 \times 10^3\ J$$

$$\boxed{1\ Btu = 1.055 \times 10^3\ J.}$$ Answer

Prob 5.2



(ii) Heat transfer for water (Q_w) =

$$2 \times c \times (17.4 - 18)$$

$$= -(2 \times 4200 \times 0.6)\ J$$

$$= -5.02\ KJ$$

(i) Heat transfer for vessel & insulation

$$Q_{vi} = m c \Delta t$$

$$= +5.02\ KJ$$

(iii) Heat transfer for vessel & insulation & Water

$$Q_{viw} = +5.02 - 5.02$$

$$= 0$$

$$\boxed{\begin{aligned} Q_{vi} &= 5.02\ KJ \\ Q_w &= -5.02\ KJ \\ Q_{viw} &= 0 \end{aligned}}$$ Answer

IMP

Prob 5.3

Given :- mass of water = 10 Kg

(i) Heat transferred to water

$$Q_w = m c \Delta t$$

$$= 10 \times 4200 \times 2.4\ J$$

$$= 100.8\ KJ$$

(ii) Heat transferred to vessel

$$Q_v = +5.02\ KJ$$

(iii) Heat transferred for steel Bar

$$Q_{SB} = -(Q_w + Q_v)$$

$$= -(100.8 + 5.02)\ KJ$$

$$= -105.82\ KJ$$

(iv) Heat transferred for vessel, insulation and the contents

$$Q_{vic} = Q_w + Q_{vi} + Q_{SB}$$
$$= (100.8 + 5.02 - 105.82)\ KJ$$
$$= 0$$

$$\boxed{\begin{aligned} Q_w &= 100.8\ KJ \\ Q_{vi} &= 5.02\ KJ \\ Q_{SB} &= -105.82\ KJ \\ Q_{vic} &= 0 \end{aligned}}$$ Answer

Prob 5.4 (i) Heat transferred to the vessel and insulation, $Q_{vi} = 5.02\ KJ$

(ii) Heat transferred for steel Bar

$$Q_{SB} = -(Q_v + Q_w)$$
$$= -(100.52 + 5.02)\ KJ$$
$$= -105.52\ KJ$$

(iii) Heat transferred to the oil

$$Q_o = Q_w$$
$$= 100.52\ KJ$$

(iv) Heat transferred to the vessel, insulation and contents $= 0$

$\boxed{5.02\ KJ, -105.52\ KJ, 100.52\ KJ, 0}$ Answer

Prob 5.5 Since the Cu Block is well insulated from the top and the sides, so there is no heat for the system comprising the vessel

Prob 5.6

	Q	W
a	−	0
b	0	+
c	+	0
d	+	−
e	0	−
f	0	−
g	0	0
h	0	−

Prob 5.7 (a) Q and W are both zero as the vessel is well insulated and sealed.

(b) W is zero as the calorimeter is sealed only. Heat is supplied by the calorimeter to the water and here calorimeter is a system, therefore Q is negative.

$$Q = -2 \times 4186 \times 0.03$$
$$= -0.251\ KJ$$

Answer

Prob 5.8 (a) Heat and work interactions are both zero as the vessel is well insulated and rigid.

(b) Insulation is removed, therefore heat interaction may takes place. In this case heat is supplied by the system as the System's temperature falls, therefore heat is negative

(c) Adding the process (a) + (b)

$W = 0$

Q is $-ve$

END

Chapter-6

The First law of Thermodynamics

6.1 (a) Stirring Work done on the contents of vessel B in ft-lbf

Since stirring work is done on the vessel B, therefore work is negative whose magnitude is given by

$$W = -\frac{2\pi \times 1485}{60} \times 40 \times 60 \times \frac{0.75}{12} \text{ ft lbf}$$

$$W = -23326 \text{ ft lbf}$$

$$\boxed{W = -23326 \text{ ft lbf}} \text{ Answer}$$

(b) Mechanical equivalent of heat in ft lbf / Btu

$$\therefore J = \frac{W}{Q}$$

$$J = \frac{23326}{30} \text{ ft-lbf/Btu}$$

$$J = 777.53 \text{ ft-lbf/Btu}$$

$$\boxed{J = 777.53 \text{ ft lbf/Btu}} \text{ Answer}$$

(c) Change in the energy of the mixture in each vessel

Since $\Delta Q - \Delta W = \Delta E$

For vessel A ; $\Delta W = 0$

$$\Rightarrow \Delta E = \Delta Q = 30 \text{ Btu}$$

for vessel (B)

$\Delta Q = 0$

$\Delta E = -(-23326)$ ft lbf

$= 23326$ ft lbf

$= 30$ Btu

$\boxed{+30\text{ Btu for each vessel}}$ Answer

6.2 @ Displacement work & the net work done by the gas during process (i)

displacement work by gas $= \dfrac{200 \times 2.8}{10 \times 10 \times 10}$ KN-m

$= +0.560$ KN-m

Net work done by gas $= (0.560 - 1.2)$ KN-m

$= -0.640$ KN-m

$\boxed{+0.560\text{ KN-m}, \; -0.640\text{ KN-m}}$ Answer

(b) Network done by the gas and the heat transfer from the gas in process (ii)

Network done by the gas $= -0.560$ KN-m

Heat transfer from the gas $= +1.2$ KJ

$\boxed{-0.560\text{ KJ}, \; +1.2\text{ KJ}}$ Answer

(c) Increase in Energy of gas in process (i) and in process (ii)

$\Delta E_1 = (1.2 - 0.560)$ KJ

$= +0.640$ KJ

$\Delta E_2 = (-1.2 + 0.560)$ KJ

$= -0.640$ KJ

$\boxed{+0.640\text{ KJ}, \; -0.640\text{ KJ}}$ Answer

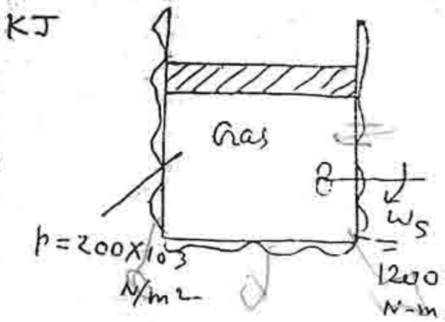
(d) Increase in energy of the gas for the combined process (i) plus (ii)

$\Delta E = \Delta E_1 + \Delta E_2$

$= (0.640 - 0.640)$ KJ

$= 0$

$\boxed{0\text{ KJ}}$ Answer



6.3

$W = -2\pi N T$

$W = -2\pi \times \dfrac{270}{60} \times 492 \times 1.5 \times 51 \times 60$ J

$W = -63.85 \times 10^6$ J

$W = -63.85$ MJ

$Q = mC\Delta t$

$Q = 173 \times 4.19 \times 10^3 \times 88$ J

$Q = 63.79 \times 10^6$ J

$Q = 63.79$ MJ

Mechanical equivalent of heat

$J = \frac{W}{Q}$

$J = \frac{63.85}{63.79}$

$\boxed{J = 1}$ Answer

Prob 6.4 The working fluid in an engine continuously executes a cyclic process.

Given

$W_1 = -15$ KJ

$W_2 = 44$ KJ

$Q_1 = 75$ KJ

$Q_2 = -40$ KJ and $Q_3 = ?$

$\Sigma W_{cycle} = \Sigma Q_{cycle}$ (for cyclic process)

$-15 + 44 = 75 - 40 + Q_3$

$Q_3 = (-15 + 44 - 75 + 40)$ KJ

$Q_3 = (84 - 90)$ KJ

$Q_3 = -6$ KJ

$\boxed{Q_3 = -6 \text{ KJ}}$ Answer

6.5

	ΔE
(a)	−
(b)	−
(c)	+
(d)	+
(e)	+
(f)	+
(g)	0
(h)	+

Answer

6.6

	ΔE
(a)	0
(b)	−

Answer

6.7

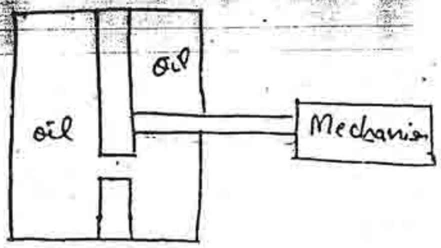
	ΔE
(a)	0
(b)	−
(c)	−

Answer

6.8

(i) $KE_1 = 4000$ N-m

$KE_2 = 0$



$\Delta E = (KE)_2 - (KE)_1$

$= (0 - 4000)$ N-m

$= -4000$ N-m Answer

(ii) $\Delta E = +4000$ N-m Answer

(iii) $\Delta E = 0$ N-m Answer

6.9 Since the gyroscope is placed inside a well insulated rigid Box,

$Q = 0$

$W = 0$

Ultimately $\Delta E = 0$ Answer

6.10 Increase in energy of the contents of the turbine casing $= 0$

(Since $W = 0$, $Q = 0$)

Answer

6.11 (a) Increase in Energy of a system

$Q = 40$ KJ

$W = 45$ KN-m

$\Delta E = Q - W$

$= (40 - 45)$ KJ

$\boxed{\Delta E = -5 KJ}$ Answer

(b) Since the second process executes b/w the same initial and final states, so the

$\Delta E = -5$ KJ

From Ist Law

$\Delta E = Q - W$

$-5 = (Q - 35)$ KJ

$\boxed{Q = 30 KJ}$ Answer

6.12. M.IMP (a) system → 3 Kg of air + N_2

$p_1 = 100$ KPa → $p_2 = 400$ KPa

$t_1 = 30°$ C → $t_2 = 90°$C

Heat transfer from the mixture $= -10$ J

Workdone on the mixture $= -64$ KJ

$\Delta E = Q - W$

$\Delta E = -10 - (-64)$ KJ

$\Delta E = (64 - 10)$ KJ

$\boxed{\Delta E = 54 KJ}$ Answer

(b) → $p_3 = 100$ KPa

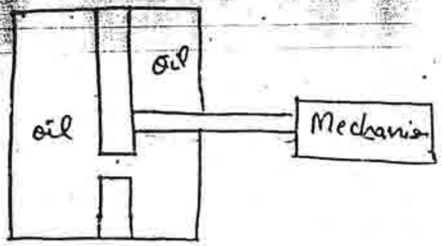
$t_3 = 30°$C

Workdone by the mixture $= 50$ KJ

(a) + (b) is a cyclic process

6.8 (i) $KE_1 = 4000$ N-m

$KE_2 = 0$



$\Delta E = (KE)_2 - (KE)_1$

$= (0 - 4000)$ N-m

$= -4000$ N-m Answer

(ii) $\Delta E = +4000$ N-m Answer

(iii) $\Delta E = 0$ N-m Answer

6.9 Since the gyroscope is placed inside a well insulated rigid Box,

$Q = 0$

$W = 0$

Ultimately $\Delta E = 0$ Answer

6.10 Increase in energy of the contents of the turbine casing $= 0$

(Since $W = 0$, $Q = 0$)

Answer

6.11 (a) Increase in Energy of a system

$Q = 40$ KJ

$W = 45$ KN-m

$\Delta E = Q - W$

$= (40 - 45)$ KJ

$\boxed{\Delta E = -5\text{ KJ}}$ Answer

(b) Since the second process executes b/w the same initial and final states, so the

$\Delta E = -5$ KJ

from Ist Law

$\Delta E = Q - W$

$-5 = (Q - 35)$ KJ

$\boxed{Q = 30\text{ KJ}}$ Answer

6.12 M.Imp (a) system → 3 Kg of air + N_2

$p_1 = 100$ KPa → $p_2 = 400$ KPa

$t_1 = 30°$ C → $t_2 = 90°$C

Heat transfer from the mixture $= -10$ J

Workdone on the mixture $= -64$ KJ

$\Delta E = Q - W$

$\Delta E = -10 - (-64)$ KJ

$\Delta E = (64 - 10)$ KJ

$\boxed{\Delta E = 54\text{ KJ}}$ Answer

(b) → $p_3 = 100$ KPa

$t_3 = 30°$C

Workdone by the mixture $= 50$ KJ

(a) + (b) is a cyclic process

$$\sum Q_{cycle} = \sum W_{cycle}$$

$$-10 + Q = 50 - 64$$

$$Q = (-64 + 50 + 10)\ KJ$$

$$\boxed{Q = -4\ KJ}$$ Answer

(c) $\Delta E = 0$ Answer

Since (a)+(b) is a cyclic process

6.13 *

	Q	W	ΔE
(i)	0	−	+
(ii)	0	+	−

(i) $Q = 0$ (given) and $W = -ve$ (stirring work)

$\Delta E = +ve$

(ii) Since Q is already zero, $W = 0$, $\Delta E =$

Answer

6.14

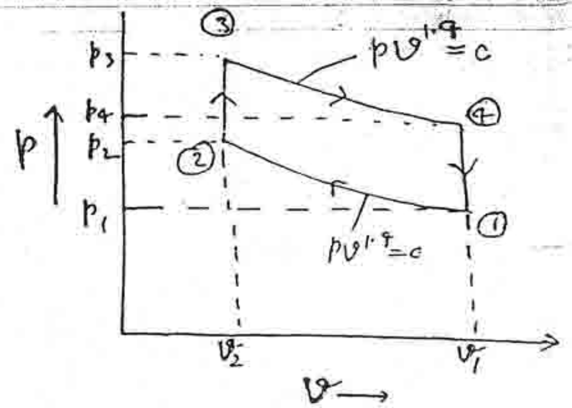
	Q	W	ΔE
(i)	0	−	+
(ii)	0	0	0

Answer

6.15

	Q	W	ΔE
(a)	0	+	−
(b)	0	+	−
(c)	−		

6.16
M. IMP



Given

$v_1 = v_4 = 1.3\ m^3/kg$

$v_2 = v_3 = 0.18\ m^3/kg$

$p_1 = 100\ KPa$

$p_3 = 3500\ KPa$

$Q_{2-3} = 840\ KJ$ (Since heat is given to system)

$Q_{1-2} = Q_{4-3} = 0$ (adiabatic compression)

Let pressure at state ② and state ④ be the p_2 and p_4 respectively

For the process 1-2

$$p_1 v_1^{1.4} = p_2 v_2^{1.4}$$

$$p_2 = p_1\left(\frac{v_1}{v_2}\right)^{1.4} \Rightarrow 100\times10^3\left(\frac{1.3}{0.18}\right)^{1.4} Pa$$

$$\boxed{p_2 = 1592.72\ KPa}$$ ✓

For the process 3-4

$$p_3 v_3^{1.4} = p_4 v_4^{1.4}$$

$$p_4 = p_3\left(\frac{v_3}{v_4}\right)^{1.4} \Rightarrow 3500\times10^3\left(\frac{0.18}{1.3}\right)^{1.4} Pa$$

$$\boxed{p_4 = 219.7\ KPa}$$ ✓

(a) Work done by air in process (i)

$$W_{1-2} = \frac{p_1 v_1 - p_2 v_2}{\gamma - 1}$$

$$W_{1-2} = \left(\frac{100 \times 1.3 - 1592.72 \times 0.18}{1.4-1}\right) \text{ KN-m}$$

$$\boxed{W_{1-2} = -392 \text{ KN-m}}$$ Answer

Workdone by the air in process (ii)

$W_{2-3} = 0$ (since volume is constant)

Work done by the air in process (iii)

$$W_{3-4} = \frac{p_3 V_3 - p_4 V_4}{\gamma - 1} \Rightarrow \frac{(3500 \times 0.18 - 2159.7 \times 1.3)}{(1.4-1)} \text{ KN-m}$$

$$\boxed{W_{3-4} = 861 \text{ KN-m}}$$ Answer

Work done by the air in process (iv)

$W_{4-1} = 0$ (since volume is constant)

(b) Heat transfer from air during process (iv)

for a cycle $\Sigma Q_{cycle} = \Sigma W_{cycle}$

$$\cancel{Q_{1-2}}^{0} + Q_{2-3} + \cancel{Q_{3-4}}^{0} + Q_{4-1} = W_{1-2} + \cancel{W_{2-3}}^{0} + W_{3-4} + \cancel{W_{4-1}}^{0}$$

$$Q_{4-1} = W_{1-2} + W_{3-4} - Q_{2-3}$$

$$= (-392 + 861 - 840) \text{ KJ}$$

$$= -371 \text{ KJ}.$$

$$\boxed{Q_{4-1} = -371 \text{ KJ}}$$

(c) Increase in ~~Internal~~ energy in process (i)

$$(\Delta E)_{1-2} = Q_{1-2} - W_{1-2}$$

$$= [0 - (-392)] \text{ KJ}$$

$$\boxed{(\Delta E)_{1-2} = 392 \text{ KJ}}$$ Answer

Increase in ~~Internal~~ energy in process (ii)

$$(\Delta E)_{2-3} = Q_{2-3} - W_{2-3}$$

$$= (840 - 0) \text{ KJ}$$

$$\boxed{(\Delta E)_{2-3} = 840 \text{ KJ}}$$ Answer

Increase in ~~Internal~~ energy in process (iii)

$$(\Delta E)_{3-4} = Q_{3-4} - W_{3-4}$$

$$= (0 - 861) \text{ KJ}$$

$$\boxed{(\Delta E)_{3-4} = -861 \text{ KJ}}$$ Answer

Increase in ~~Internal~~ energy in process (iv)

$$(\Delta E)_{4-1} = Q_{4-1} - W_{4-1}$$

$$= (-371 - 0) \text{ KJ}$$

$$\boxed{(\Delta E)_{4-1} = -371 \text{ KJ}}$$ Answer

Prob 6.17

(a) Since an insulated rigid vessel is system

$\delta Q_1 = 0$

$\delta W_1 = 0$

$\boxed{dE_1 = 0}$ Answer

(b) $\Delta E_2 = Q_2 - W_2$

$\Delta E_2 = (-45 - 0)\ KJ$

$\boxed{\Delta E_2 = -45\ KJ.}$ Answer

(c). Take intial energy of the system $= 30\ KJ$

Energy after the process (a)

$\Delta E_a = E_i + E_1$

$= (30 + 0)\ KJ$

$= 30\ KJ$

Energy after the process (b)

$\Delta E_b = E_i + E_1 + E_2$

$= (30 + 0 - 45)\ KJ$

$= -15\ KJ$

$\boxed{30\ KJ,\ -15\ KJ}$ Answer

Prob 6.18

Increase in Energy of contents of cylinder

$Q = -4\ KJ$

Swept volume = Area of piston × swept length

$\Delta V = \frac{\pi}{4} \times (100 \times 10^{-3})^2 \times (85 \times 10^{-3})\ m^3$

$\Delta V = 6.676 \times 10^{-4}\ m^3$

Workdone, $W = p\Delta V$

$W = 240 \times 10^3 \times 6.676 \times 10^{-4}\ N{\cdot}m$

$W = 0.160\ KJ$

Using Ist Law of thermodynamics

$\Delta E = Q - W$

$\Delta E = (-4 - 0.160)\ KJ$

$= -4.16\ KJ$

$\boxed{\Delta E = -4.16\ KJ}$ Answer

6.19 M.IMP

(a) Given

Initial energy of the system = 10 KJ

Since a system consisting of a mixture of air & gasoline vapour is contained in a rigid vessel.

The Workdone in each process become zero

Energy of the system after process (i)

$\Delta E_1 = 3\ KJ$

$E_{ai} = (3+10)\ KJ$

$\boxed{E_{ai} = 13\ KJ}$ Answer

$\Delta E_2 = 0$

$E_{aii} = (3+10+0)\ KJ$

$\boxed{E_{aii} = 13\ KJ}$ Answer

$\Delta E_3 = -32\ KJ$

$E_{aiii} = (13-32)\ KJ$

$\boxed{E_{aiii} = -19\ KJ}$ Answer

(b) Given: An equal mass of same mixture is contained in a cylinder closed by a piston.

Workdone during process (i)

$\Delta E = Q - W$

$\Delta E = 0 - W$

$W = -\Delta E_{bi}$

Since energy of the system depends only on its temperature & chemical aggregation

$\boxed{\Delta E_{bi} = \Delta E_1}$

$= 3\ KJ$

$\boxed{W_{bi} = -3\ KJ}$ Answer

Heat transfer during process (iii)

Workdone by the system

$W = +\ 31\ KJ$

Energy of the system

$\Delta E_{biii} = \Delta E_3$

$= -32\ KJ$

Using I[st] law of Thermodynamics

$\Delta E_{biii} = Q_{biii} - W_{biii}$

$Q_{biii} = \Delta E_{biii} + W_{biii}$

$Q_{biii} = (-32+31)\ KJ$

$Q_{biii} = -1\ KJ$

$\boxed{Q_{biii} = -1\ KJ}$ Answer

END

[CHAPTER-7]

[THE PURE SUBSTANCES]

7.1) Given,

The mass of pure substance $m = 2.5\,Kg$.

$P_1 = 700\times10^3\,N m^{-2}$

$t_1 = 200^\circ C$

$v_1 = 0.2\,m^3/Kg$

$P_2 = 700\times10^3\,N m^{-2}$

$v_2 = 0.2\,m^3/Kg$

(a) The initial and final states of the system are same as pressure and specific volume are independent properties; so the final temp is 200°C.

Therefore,

Increase in specific internal energy $(\Delta u) = 0$

-Ans

(b) Work done by system = 1200 N-m

$\Delta E = 0$

By first law of thermodynamics-

$Q - W = \Delta E$ $\quad W = 12,000$

$\Rightarrow Q = 1200\,J$.

-Ans

7.2) Given,

Internal energy $= -10\times10^3\,J$.

Heat transfer to system $= +6\times10^3\,J$.

(a) By first law of thermodynamics-

$\Delta E = Q - W$

$-10\times10^3 = +6\times10^3 - W$

$\Rightarrow W = 16\times10^3\,J$.

Ans

(b) If $W=0$

$Q - W = \Delta E$

$Q = \Delta E$

$= -10\times10^3\,J$.

-Ans

7.3) Given, $m = 4.2\,kg$

$E_1 = 85.7\,KJ$. $\quad K_1 = 13.6\,kNm$

$K_2 = 1.15\,kNm$ $\quad P_1 = 4.9\,kNm$

$P_2 = 0.85\,kNm$ $\quad u_1 = 159\,KJ/Kg$

$U_2 = 159\times4.2 = 667.8\,KJ$.

(a) $E = K + U + P$

$\Rightarrow K_1 + P_1 + U_1 = E_1$

$\Rightarrow U_1 = E_1 - (K_1 + P_1)$

$= 85.7 - (13.6 + 4.9)$

$= 67.2\,KJ$.

Specific volume $v_1 = \frac{67.2}{4.2} = 16\,KJ/kg$

-Ans

(b) Change in K.E. $(\Delta K) = K_2 - K_1$

$= (1.15\times10^3 - 13.6\times10^3)\,N\text{-}m$

$= -12.45\times10^3\,N\text{-}m$.

Change in P.E. $= \Delta P = P_2 - P_1$

$= 850 - 4.5\times10^3$

$= -4.05\times10^3\,N\text{-}m$.

Change in internal energy $\Delta U = U_2 - U_1$

$= 667.8\,KJ - 67.2\,KJ$

$= 600.6\,KJ$.

$\Delta E = \Delta K + \Delta P + \Delta U$

$= (-12.45\times10^3 - 4.05\times10^3 + 600.6\times10^3)\,J$.

$\Delta E = 584.1\ KJ.$

By first law,

$Q - W = \Delta E$

$Q = 0$ because process is adiabatic.

$0 - W = 584.1\ KJ$

$W = -584.1\ KJ.$

—Ans

(c) Since effects of gravity and motion are negligible,

$\Delta K = 0$ and $\Delta P = 0$

$\Delta U = U_2 - U_1 = 600.6\ KJ.$

$W = -600.6\ KJ.$

—Ans

7.4) Given $m = 0.3\ Kg$

$P = 90 \times 10^3\ Nm^{-2}$; $T = 40^\circ c$

$V = 120\ dm^3 = 120 \times 10^{-3} m^3$

Internal energy of the substance $U = 30.4 \times 10^3 J.$

Therefore, Enthalpy of substance

$H = U + PV$

$= 30.4 \times 10^3 + 90 \times 10^3 \times 120 \times 10^{-3}$

$= 41200 J$

Therefore, specific enthalpy $(h) = \frac{H}{m}$

$= \frac{41200}{0.3} = 137.3\ KJ/kg$

—Ans

7.5)

For displacement work,

$dW = PdV$

or $\int dW = \int PdV$

$\Rightarrow W = P\int dV$ (since pressure is held constant)

$W = P\Delta V$ —(1)

By first law of thermodynamics,

Change in energy $(\Delta E) = Q - W$ (where Q is heat)

In the system, there is change in internal energy

$\Rightarrow \Delta U = Q - W$

or $Q = \Delta U + W$

$= \Delta U + P\Delta V$

We know that,

$\Delta H = \Delta U + P\Delta V$

$\therefore Q = \Delta H$

$\Rightarrow$ Heat transfer during the process is equal to the change in enthalpy.

Hence Proved

7.6)

The work done due to expansion i.e. displacement work $(W_d) = P\Delta V$

Let Work done by shaft be (W_{shaft}) and volume swept by system be ΔV.

From I^{st} law, change in internal energy-

$\Delta E = Q - W$

Since the energy changes are only internal energy.

Therefore, $\Delta K = Q - W_{Total}$

$\Delta U = -W_{Total}$ (as $Q = 0$)

But $W_{Total} = W_d + W_{shaft}$

$= P\Delta V - W_{shaft}$

$\Rightarrow \Delta U = -(P\Delta V - W_{shaft})$

$\Rightarrow W_{shaft} = \Delta U + P\Delta V$

$= \Delta H$

$\Rightarrow W_{shaft} = \Delta H$

$\therefore$ Work done by the stirrer is equal to change in enthalpy of system.

Hence Proved

7.7) Given process are held at constant temp. and pressure.

Also, specific heat at constant volume is defined as the rate of change of specific internal energy of the system with time when specific volume is held constant.

Therefore →

$$C_v = \left(\frac{du}{dT}\right)_v$$

$\Rightarrow C_v\, dt = du$

$\Rightarrow \Delta u = C_v \Delta t$ (where Δ denotes small change)

Similarly,

$$C_p = \left(\frac{dH}{dt}\right)_p$$

$\Rightarrow C_p \delta t = \delta H$

$\Delta H = C_p \Delta T$ (where Δ = small change)

Hence Proved

7.8) Given $\Delta u = C_v \Delta t$

$\Delta h = C_p \Delta t$

(a) $C_v = 4186\ J/kgK$ $m = 1\,kg$

$\therefore$ Increase in internal energy for 1 kg of water at 100°C

$\Delta u = (4186 \times 1 \times 100)\,J$

$= 418.6\,KJ.$

—Ans

(b) $C_p = 2093\ J/kg\,K$ $m = 2\,kg$

Increase in enthalpy for 2 kg of ice at constant volume from 20°C to 0°C

$\Delta H = (2093 \times 2 \times 20)$

$= 83.72\,KJ.$

—Ans

c) Given $m = 3\,kg$, $C_v = 718\,J/kg\,K$

$C_p = 1005\,J/kg\,K$, Initial temp. $= 60°C$

Final temp. $= 5°C$, $P_{initial} = 400 \times 10^3\ Nm^{-2}$

$P_{final} = 300 \times 10^3\ Nm^{-2}$

(i) Increase in internal energy $\Delta u = mC_v\Delta t$

$\Delta u = 3 \times 718\,(5 - 60)$

$= -118500\,J$

$= -118.5\,KJ.$

—Ans

(ii) Increase in enthalpy of air $\Delta H = mC_p\Delta t$

$\Delta H = 3 \times 1005 \times (5 - 60)$

$= -165825\,J.$

$= -165.8\,KJ.$

—Ans

(iii) No only $Q - W$ be calculated.

$\Delta u = C_v dT$

$\Delta h = C_p dT$

7.9) Given,

$Pv = 260t + 71\times10^3$

$t = 1.52u - 273$

Specific heat at constant volume,

$c_v = \frac{du}{dt}$

$t = 1.52u - 273$

$\frac{dt}{du} = 1.52$ or $\frac{du}{dt} = \frac{1}{1.52}$

$\Rightarrow c_v = 0.658$ KJ/Kg.K.

Specific heat at constant pressure,

$c_p = \frac{dH}{dt}$

$h = u + Pv$

$h = \frac{t+273}{1.52} + 0.26t + 71$

Differentiating both sides w.r.t. t

$\frac{dh}{dt} = \frac{1}{1.52} + 0.26$

$= 0.918$ KJ/Kg.K

-Ans

(b) Since the internal energy and enthalpy are the functions of temperature only. Therefore.

$\Delta h = c_p \Delta t$

$\Delta H = c_v \Delta t$

(c) Given $m = 1$ Kg $P_1 = 600\times10^3 Nm^{-2}$

$t_1 = 280°C$ $\Delta H = 28$ KJ/Kg

$Q = +ve$

$\Delta H = mc_p \Delta t$

$28 = 1\times 0.918 \times \Delta t$

$\Delta t = t_2 - t_1 = 30.5°C$

$t_2 = t_1 + \Delta t$

$= 280 + 30.53°C$

$= 310.53°C$

Also,

$\Delta U = mc_v \Delta t$

$= 1\times 0.658 \times 30.5$

$= 20.069$ KJ.

By first law,

$\Delta U = Q - W$

$W = 0$ (as the vessel is rigid)

$\Delta U = Q = 20.069$ KJ.

$P_2V_2 = 260\times310.53 + 71\times10^3$

$= 151730$

$P_1V_1 = 260\times280 + 71\times10^3$

$= 143800$

$\because V_1 = V_2$ (vessel rigid)

$\Rightarrow P_2 = \frac{151730}{143800} P_1$

$= 633.08\times10^3 Nm^{-2}$

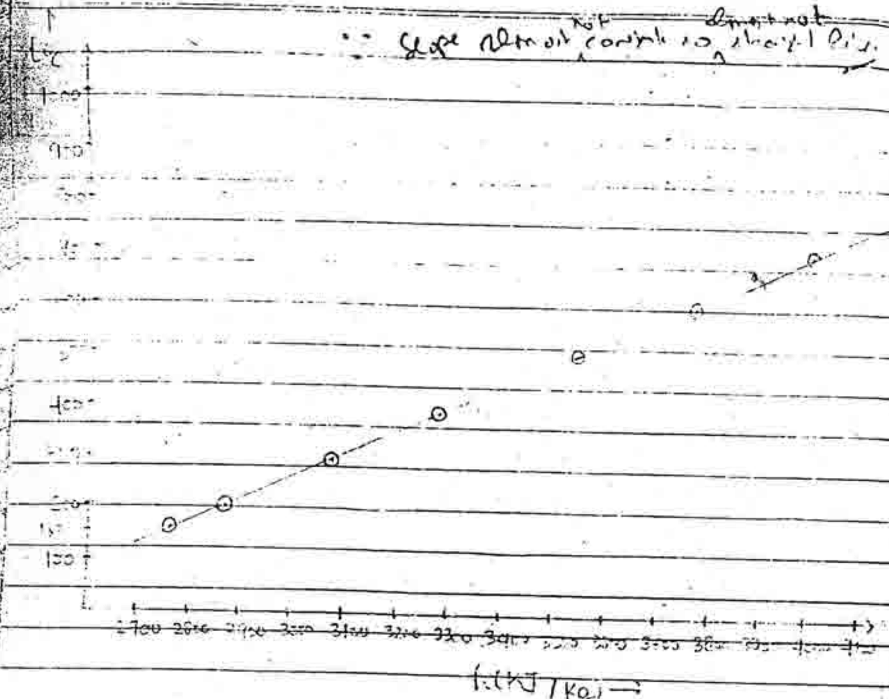
-Ans

7.10) Given,

$P = 200\times10^3 Nm^{-2}$

$t°C$	150	200	300	400	500	600	700
h (KJ/Kg)	2763.5	2870.5	3072.5	3276.7	3437.0	3704.6	3927.6

Graph is



$$C_p = \frac{dh}{dt}$$

or $dh = C_p\,dt$

or $\Delta h = C_p \Delta t$ where Δ denotes a small change

(a) $$C_p = \frac{\Delta h}{\Delta t}$$

at temp. 200°C. Let us assume a small change of 50°C from 150°C to 200°C.

$$C_p = \frac{(2870.5 - 2768.5)}{200-150}$$

$$= 2.04\,KJ/kg.K.$$

—Ans

(b) At temp. 650°C $h = 3810\,KJ/Kg$

at temp 600°C $h = 3704\,KJ/Kg$

from, $C_p = \frac{\Delta h}{\Delta t}$

Taking small interval of 50°C.

$$C_p = \frac{3810-3704}{650-600}$$

$$= 2.20\,KJ/Kg.K.$$

—Ans

7.11) Given – $Pv = 310\,(t+273)$

and $u = u_0 + 0.84t$

$V_1 = 0.02\,m^3$ $\quad P_1 = 350\times10^3\,Nm^{-2}$ $\quad \frac{V}{m} = v$

$t_1 = 80°C$ $\quad W = 2900\,J$

(a) $PV = 310\,(t+273)$

$P\frac{V}{m} = 310(t+273)m$

$PV = 310(t+273)m$

$$\boxed{m = \frac{PV}{310(t+273)}}$$

$$= \frac{350\times10^3\times0.02}{310(80+273)} = \underbrace{0.064\,Kg}$$

$u = u_0 + 0.84t$

$mu = mu_0 + 0.84t.m$

$m(u-u_0) = 0.84tm$

$\Delta U = 0.84m\Delta t$

$\Delta U = .84\,m(t_2-t_1)$

$Q - W = 0.84m(t_2-t_1)$

$$\frac{-1900-2900}{1000} = 0.84\times0.064\,(t_2-80)$$

$\Rightarrow t_2 = -9.28°C$ —Ans

$q - W = \Delta U$

$-1900 - 2900 = \Delta U$

$\Delta U = -4800$

$\Delta U = \frac{-4800}{1000\times0.064}$

$\frac{-4800}{1000\times0.064} = 0.84(t_2-80)$

First law of thermodynamics-

$\Delta u = Q - W$

For adiabatic process $Q = 0$

$\Delta u = -W$

$W = 4.8\ kN\text{-}m$

-Ans

7.12) (a) Given,

$m = 0.95\ Kg$ $\quad u = 16\ KJ/Kg$

$v = 120\ ms^{-1}$ $\quad h = 1500\ m$

$E = u + mgh + \frac{1}{2}mv^2$

$= mu + mgh + \frac{1}{2}mv^2$

$\Delta E = 0.95 \times 16 \times 10^3 + 0.95 \times 9.81 \times 1500 + \frac{1}{2} \times 0.95 \times (120)^2$

$= 36019.2.5\ J = 36.02\ KJ$

-Ans

(b) Given, $u = 20\ KJ/Kg$ $\quad v = 200\ ms^{-1}$

$h = 270\ m$ $\quad W = -2200\ N\text{-}m$

$\Delta E = mu + mgh + \frac{1}{2}mv^2$

$= 0.95 \times 20 \times 10^3 + 0.95 \times 9.81 \times 270 + \frac{1}{2} \times 0.95 \times (200)^2$

$= 21535.26\ J$

$= 21.5\ KJ$

-Ans

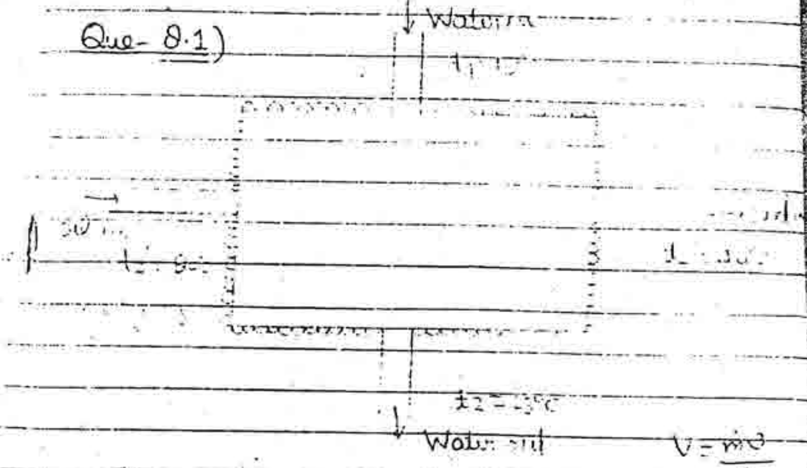
$Q - W = \Delta E$

$= (40.516263 - 36.02) \times 10^3 - 2200$

[CHAPTER-8]

[THE FIRST LAW APPLIED TO FLOW ...]

Que- 8.1)



$V = \frac{m}{\rho}$

Given, $h = c(t - t_0)$

$C_{water} = 4.18 \times 10^3\ J/Kg\,K$

$C_{oil} = 1.88 \times 10^3\ J/Kg\,K$

FOR OIL:-

$\Delta H_{oil} = C_o(t_2' - t_1')$

$= 1.88 \times 10^3 (40 - 80)$

$= -7.52 \times 10^4\ J/Kg$

Using S.F.E.E. for single stream

$\frac{\cancel{Q} - W_x}{m_{oil}} = \Delta\left(H + \frac{V^2}{2g_c} + \frac{gz}{g_c}\right)$

$\Rightarrow -W_x = 0.08 \times (-7.52 \times 10^4)$

$W_x = 6.016 \times 10^3\ J/s.$

FOR WATER:-

$\Delta H_{water} = C_o(t_2 - t_1)$

$= 4.18 \times 10^3 (25 - 15)$

$= 41.8 \times 10^3\ J/Kg$

Again appling S.F.E.E. for water-

$$\frac{\cancel{Q}^{0}-W_x}{m}=\Delta\left(H+\cancel{\frac{V^2}{2g_c}}^{0}+\cancel{\frac{gz}{g_c}}^{0}\right)$$

$$\Rightarrow \frac{-W_x}{m}=\Delta h_{water}$$

$$m_{water}=\frac{6.016\times10^3\ J/s}{41.8\times10^3\ J/Kg}$$

$$m_{water}=0.144\ Kgs^{-1}$$

-Ans

8.2) Given, $H_1=246.9\times10^3\ J/Kg$

$P_1=300\times10^3\ N/m^2$

$t_1=59^\circ c$ $\quad H_2=196.8\times10^3\ J/Kg$

$P_2=280\times10^3\ N/m^2$ $\quad t_2=47^\circ c$

$\Delta z=30.5\ m.$

Appling S.F.E.E. for single stream

$$\frac{Q-\cancel{W_x}^{0}}{m}=\Delta\left(H+\cancel{\frac{V^2}{2g_c}}^{0}+\frac{gz}{g_c}\right)$$

$$\frac{Q}{m}=\Delta\left(H+\frac{gz}{g_c}\right)$$

$$Q=H_2-H_1+g\,\Delta z$$

$$=-\cancel{50}.1\times10^3+9.81\times(+30.5)$$

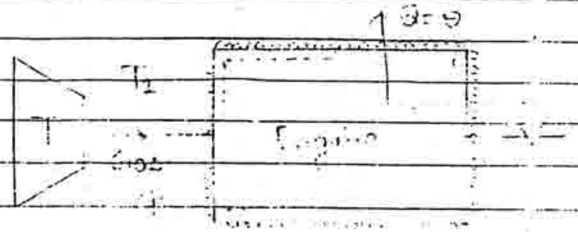
$$=-\cancel{50}.1\times10^3+299.20$$

$$=-49.8\ KJ/Kg$$

$\therefore$ Heat transfer from water are -49.8 KJ/Kg

-Ans

8.3)



Given,

$T_1=900^\circ c$ $\quad P_1=1.92$ bar

$v_1=300\ ms^{-1}$ $\quad T_2=820^\circ c$

$P_2=1.05$ bar.

$t^\circ c$	820	900
h (J/Kg)	862.6	951.7

Using S.F.E.E. for single stream across the engine-

$$\frac{\cancel{Q}^{0}-\cancel{W_x}^{0}}{m}=\Delta\left(H+\frac{V^2}{2g_c}+\cancel{\frac{gz}{g_c}}^{0}\right)$$

(Q=0 because engine is insulated and W=0 ∵ no work is done)

$$\Rightarrow \Delta\left(H+\frac{V^2}{2g_c}\right)=0$$

$$\Rightarrow (H_2-H_1)+\frac{1}{2}(V_2^2-V_1^2)=0$$

$H_2\ (820^\circ c)=862.6$ KJ/Kg

$H_1\ (900^\circ c)=951.7$ KJ/Kg

$$\Rightarrow 10^3(862.6-951.7)+\frac{1}{2}(V_2^2-300^2)=0$$

$$V_2=517.88\ ms^{-1}$$

$$=518\ ms^{-1}$$

-Ans

8.4)

Given, $T_1 = 16°C$ $P_1 = 1 \text{ bar}$

$H_1 = 391.2 \text{ KJ/Kg}$

$T_2 = 245°C$ $P_2 = 6 \text{ bar}$

$H_2 = 534.5 \text{ KJ/Kg}$

(a) Using S.F.E.E. for single stream –

$$\frac{\cancel{Q}^{0} - W_x}{m} = \Delta\left(H + \cancel{\frac{V^2}{2g_c}}^{0} + \cancel{\frac{gz}{g_c}}^{0}\right)$$

$\Rightarrow -\left(\frac{W_x}{m}\right) = \Delta H$ (as entry and exit velocities are negligible)

$$\left(\frac{W_x}{m}\right) = H_2 - H_1$$

$$= (534.5 - 391.2) \text{ KJ/Kg}$$

$$\frac{W_x}{m} = -143.3 \times 10^3 \text{ J/Kg}$$

(b) Again from S.F.E.E.

$$-\left(\frac{W_x}{m}\right) = \Delta H + \frac{1}{2}(V_2^2 - V_1^2)$$

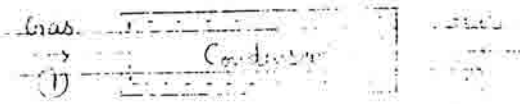
$$-\left(\frac{W_x}{m}\right) = 143.3 \text{ KJ/Kg} + \frac{1}{2}(160^2 - 80^2)$$

$$= (143.3 \times 10^3 + 5.6 \times 10^3) \text{ KJ/Kg}$$

$$\left(\frac{W_x}{m}\right) = -152.9 \times 10^3 \text{ J/Kg}$$

– Ans

8.5)



Given,

$m = 1.2 \text{ kg/s}$ $H_1 = 2.3 \times 10^6 \text{ J/Kg}$

$v_1 = 18.5 \text{ m}^3\text{/Kg}$ $H_2 = 190 \times 10^3 \text{ J/Kg}$ $V_2 = 0$

$Q = 70 \times 10^3 \text{ J/s}$

(a) $A_1 = 0.2 \text{ m}^2$

$$m = \frac{V_1 A_1}{v_1}$$

$$\Rightarrow 1.2 \text{ Kg s}^{-1} = \frac{V_1 \times 0.2 \text{ m}^2}{18.5 \text{ m}^3\text{/Kg}}$$

$$V_1 = 111 \text{ ms}^{-1}$$

(b) Applying S.F.E.E. for single stream.

$$\frac{Q - \cancel{W_x}^{0}}{m} = \Delta\left(H + \frac{V^2}{2g_c}\right)$$

$$\frac{Q}{m} = H_2 - H_1 + \frac{V_1^2}{2g_c}$$

$$= -2.11 \times 10^6 \text{ J/Kg} + \frac{(111)^2}{2}$$

$$= -2103.8 \times 10^3 \text{ J/Kg}$$

$$\left(\frac{Q}{m}\right)_{Total} = -2103.8 \text{ KJ/Kg}$$

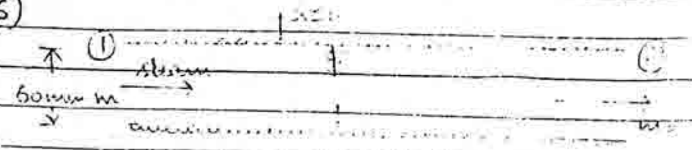
$$\left(\frac{Q}{m}\right)_{atm} + \left(\frac{Q}{m}\right)_{C.W.} = \left(\frac{Q}{m}\right)_{Total}$$

$$\left(\frac{Q}{m}\right)_{C.W.} = \left(-2103.8 + \frac{70}{1.2}\right) \text{ KJ/Kg}$$

$$\left(\frac{Q}{m}\right)_{C.W.} = -2045.83 \text{ KJ/Kg}$$

– Ans

Q.6)



Given,

$d = 60\,mm$

$P_1 = 2\times10^6\,Nm^{-2}$ $P_2 = 200\times10^3\,Nm^{-2}$

$m = 0.03\,kg/s$ $H_1 = 2.77\times10^6\,J/kg$

(a)

Using S.F.E.E for single stream-

$$\frac{\cancel{Q}^0 - \cancel{W_x}^0}{m} = \Delta\left(H + \cancel{\frac{V^2}{2g_c}}^0 + \cancel{\frac{gz}{g_c}}^0\right)$$

$\Rightarrow \Delta H = 0$

$H_1 = H_2$

$\Rightarrow H_2 = 2.77\times10^6\,J/kg$

- Ans

(b) Given,

$v_1 = 0.0980\,m^3/kg$ $v_2 = 0.9602\,m^3/kg$

Using, $m = \frac{V_1 A_1}{v_1}$

$\Rightarrow 0.03 = \frac{V_1\times\pi\times(0.06)^2}{4\times0.0980} - 1.04\,ms^{-1}$

Also,

$m = \frac{V_2 A_2}{v_2} = \frac{V_2\times\pi/4(0.06)^2}{0.9602}$ $\frac{\Delta V^2}{2g_c}$ is $<<\Delta H$

$V_2 = 10.19\,ms^{-1}$

- Ans

Q.7) Given,

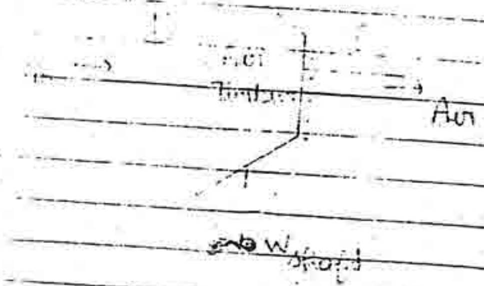
$P_1 = 2.95\,bar$ $T_1 = 58°C$

$V_1 = 45\,ms^{-1}$ $P_2 = 1.15\,bar$

$T_2 = 2°C$ $V_2 = 150\,ms^{-1}$

$W_{shaft} = 54\,KJ/kg$

C_p (for air) $= 1005\,J/kg\,K$ and $H = f(T)$



$\Delta H = H_2 - H_1 = C_p\Delta t$

$= \frac{-1005\,J}{kg\,K}\times56\,K$

$= -56280\,J/kg$

$\Delta H = -56.28\,KJ/kg$

Using S.F.E.E for single stream.

$$\frac{Q - W_x}{m} = \Delta\left(H + \frac{V^2}{2g_c} + \cancel{\frac{gz}{g_c}}\right)$$

$$\left(\frac{Q}{m}\right) - \left(\frac{W_x}{m}\right)_{shaft} = \Delta H + \Delta\left(\frac{V^2}{2g_c}\right)$$

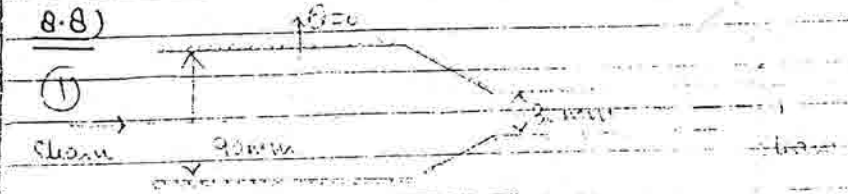
$$\left(\frac{Q}{m}\right) - 54\,KJ/kg = -56.28\,KJ/kg + \frac{1}{2}(150^2 - 45^2)$$

$$\left(\frac{Q}{m}\right) = 7.96\,KJ/kg$$

i.e. 7.96 KJ/kg heat is given to system.

- Ans

8.8)



Given, $d_1 = 90\,mm$ $d_2 = 30\,mm$

$P_1 = 3.5\,bar$ $v_1 = 0.684\,m^3/Kg$

$H_1 = 2.98\times10^6\,J/Kg$

$P_2 = 3\,bar$ $v_2 = 0.790\,m^3/Kg$

$H_2 = 2.968\times10^6\,J/Kg$

By the continuity equation mass flow rates of the steam remains same i.e.

$$\frac{V_1A_1}{v_1} = \frac{V_2A_2}{v_2}$$

$$\Rightarrow V_1 \times \frac{\pi}{4}\times\frac{(0.09)^2}{0.684} = V_2\times\frac{\pi}{4}\times\frac{(0.03)^2}{0.790}$$

$$\Rightarrow V_2 = V_1(10.39) \text{ — (1)}$$

Also, using S.F.E.E. for single stream

$$\frac{\cancel{Q}^{0}-\cancel{W_x}^{0}}{m} = \Delta\left(H+\frac{V^2}{2g_c}+\cancel{\frac{gz}{g_c}}^{0}\right)$$

$$\Rightarrow H_2 - H_1 + \frac{1}{2}(V_2^2 - V_1^2) = 0$$

$$V_2^2 - V_1^2 = 24\,KJ/Kg \text{ — (2)}$$

Substituting the value of V_2 in (2)

$$[V_1(10.39)]^2 - V_1^2 = 24\,KJ$$

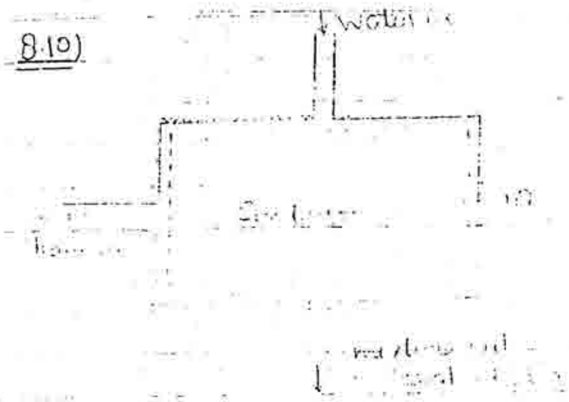
$$\Rightarrow V_1 = 14.97\,ms^{-1}$$

$$V_2 = 14.97\times10.39 = 155.64\,ms^{-1}$$

Also $m = \frac{A_1V_1}{v_1} = \frac{14.97\times\pi/4\times(0.09)^2}{0.684}$

$= 0.139\,Kg\,s^{-1}$ — Ans

8.10)



Given,

$H_s = 2.3\times10^6\,J/Kg$

$m_s = 0.06\,kg/s$

$H_m = 340\times10^3\,J/Kg$

$H_w = 70\times10^3\,J/Kg$

$m_m = m_w + m_s$

Using S.F.E.E. for mixture steam

$$\overset{0}{Q} - W = \sum_{out} m\Delta\left(H + \cancel{\frac{V^2}{2g_c}} + \cancel{\frac{gz}{g_c}}\right) - \sum_{in} m\Delta\left(H + \cancel{\frac{V^2}{2g_c}} + \cancel{\frac{gz}{g_c}}\right)$$

$$\Rightarrow 0 = (m_s + m_w)(340\times10^3) - 0.06(2.3\times10^6) - m_w(70\times10^3)$$

$$\Rightarrow 20.4\times10^3 + m_w\times340\times10^3 - 138\times10^3 - m_w\times70\times10^3 = 0$$

$$\Rightarrow m_w(270\times10^3) = 117.6\times10^3$$

$$m_w = \frac{117.6\times10^3}{270\times10^3}\,kg\,s^{-1}$$

$= 0.4355\,kg\,s^{-1}$

$= 0.436\,kg\,s^{-1}$

— Ans

Q.11)

Given,

$m_{s1} = 0.01\ \text{Kg/s}$, $H_{s1} = 2.952\times10^6\ \text{J/Kg}$

$u_{s1} = 20\ \text{ms}^{-1}$, $m_{s2} = 0.1\ \text{Kg s}^{-1}$

$H_{s2} = 2.569\times10^6\ \text{J/Kg}$, $u_{s2} = 120\ \text{ms}^{-1}$

$m_w = 0.001\ \text{Kg/s}$, $H_w = 420\times10^3\ \text{J/Kg}$

$W_{shaft} = 25\times10^3\ \text{J/s}$, $Q = 0$

Using S.F.E.E. for multistream-

$$Q - W_x = m\sum_{out}\left(H + \frac{v^2}{2g_c} + \cancel{\frac{gz}{g_c}}\right)^0 - m\sum_{in}\left(H + \frac{v^2}{2g_c} + \cancel{\frac{gz}{g_c}}\right)^0$$

Also, from continuity equation-

$$m_{in} = m_{out}$$

$$\Rightarrow m_{s1} + m_{s2} = m_{w\,out} + m_{s\,out}$$

$$\Rightarrow 0.01 + 0.1 = 0.001 + m_{s\,out}$$

$$m_{s\,out} = 0.109\ \text{kg s}^{-1}$$

$$\Rightarrow -25\times10^3\times\omega = 0.01\,(2.95\times10^6 + 200) + 0.1\,(2.569\times10^6 + \tfrac{1}{2}\times120^2)$$

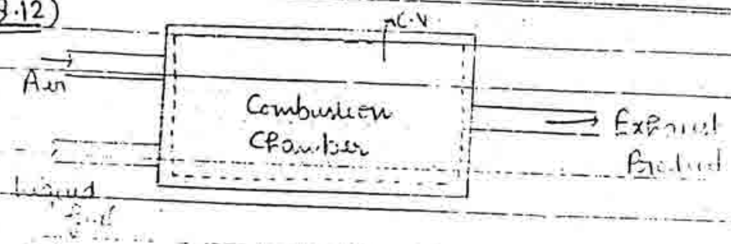
$$-0.109\,(h) - 0.001\,(420\times10^3\ \text{J/Kg})$$

$$\Rightarrow -25\times10^3 - 2.952\times10^4 - 2 - 2.59\times10^5 - 720 + 420 = 0.109h$$

$$\Rightarrow h = 2.859\times10^6\ \text{J/Kg}$$

— Ans

Q.12)



Given,

$m_a = 15\ \text{Kg/s}$ $m_{fuel} = 0.22\ \text{Kg/s}$

$m_{air} + m_{fuel} = m_p$

$$15\ \text{Kg/s} + 0.22\ \text{Kg/s} = m_p$$

$$m_p = 15.22\ \text{Kg/s}$$

$$m_{products} = 15.22\ \text{Kg/s}$$

Using S.F.E.E. for multistream-

$$Q - W = m\sum_{out}\left(H + \frac{v^2}{2g_c} + \cancel{\frac{gz}{g_c}}\right)^0 - m\sum_{in}\left(H + \frac{v^2}{2g_c} + \cancel{\frac{gz}{g_c}}\right)^0$$

$$m_{air}\times\left(H_a + \frac{v^2}{2}\right) + m_{fuel}\left(H\times\frac{v^2}{2}\right) - m_p\left(u_p + \frac{v^2}{2}\right) = 0$$

$$\Rightarrow 15\,(176.2\times10^3 + 5000) + 0.22\,(h) - 15.22\left(787.5\times10^3 + \frac{200^2}{2}\right) = 0$$

$$\Rightarrow 2.718\times10^6 + 0.22h = 12.29\times10^6$$

$$h = 43500\ \text{kJ/Kg}$$

— Ans

[CHAPTER-9]

[PROPERTIES OF PURE SUBSTANCES]

9.1) (a) Given, saturated water pressure $= 6\times10^3\,Nm^{-2}$
$= 0.06$ bar

From Pressure table $v_f = 0.001064\,m^3/kg$

(b) Given dry saturated steam $t = 200°C$
From temp. table
$v_g = 0.12716\,m^3/kg$

(c) Given - Saturated water pressure $= 1.01\cdot2\times10^{-4}\,Nm^{-2}$
$= 1.01325$ bar

Saturated temp. $= 100\cdot00°C$

(d) Given, dry saturated steam $P = 1.0132$ bar
Saturated temp. $= 100°C$

(e) Given, wet steam $x = 0.9$ $P = 1.01325$ bar
saturated temp. $= 100°C$

(f) Given pressure $= 6.3$ bar
at 6 bar $h_{fg_1} = 2085.0\,KJ/kg$
at 7 bar $h_{fg_2} = 2064.9\,KJ/kg$
at 6.3 bar -
$h_{fg} = 2085 - \frac{0.3}{1}(2085 - 2064.9)$

$= 2078.97\,KJ/kg$

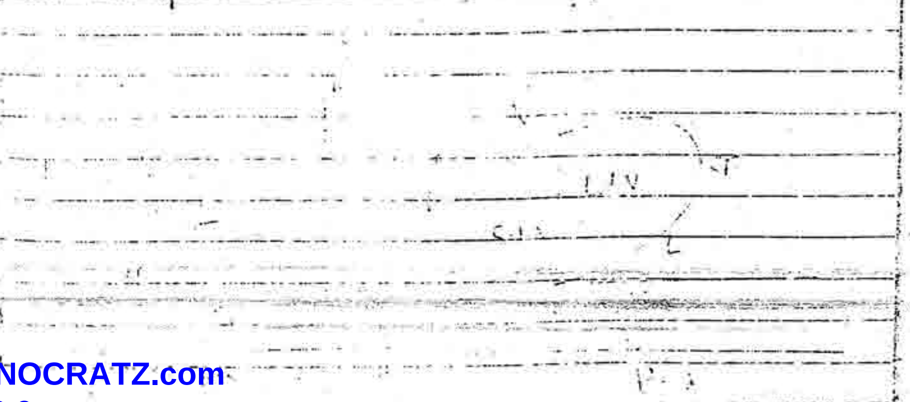
(g) Given, Dry saturated vapour $t = 100°C$
$\therefore h_g = 2676.0\,KJ/kg$

(h) Given,
Pressure $= 3.75\times10^6\,N/m^2$
$= 37.5$ bar
Internal energy (u_1) at 35 bar $= 1045.4\,KJ/Kg$
Internal energy (u_2) at 40 bar $= 1082.4\,KJ/Kg$
By interpolation
at $P = 37.5$ bar
$u = 1045.4 + \frac{2.5}{5}(37)$

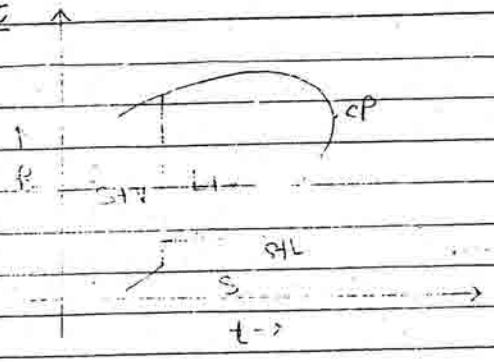
$= 1063.9\,KJ/Kg$

(i) Given steam $P = 400\times10^3\,Nm^{-2} = 4$ bar
$t = 400°C$
Specific volume $v = 0.7725\,m^3/kg$
Enthalpy $(h) = 3273.6\,KJ/Kg$
Internal energy $u = h - pv$
$= 3273.6 - 400\times0.7725$
$= 2964.6\,KJ/Kg$

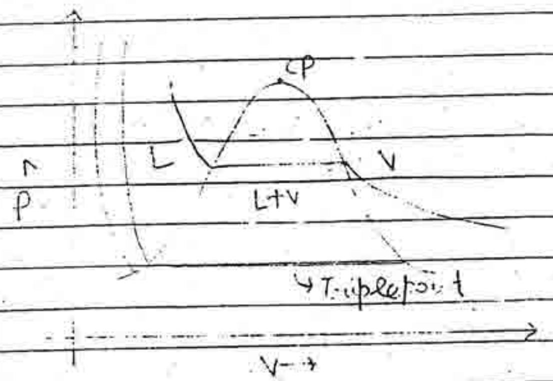
9.2) Phase diagram of H_2O
(a) $t \sim p$ (b) $h \sim p$



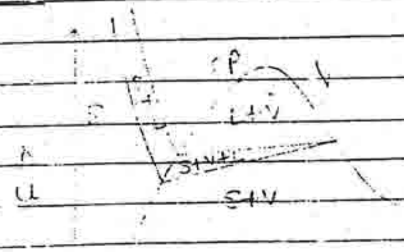
(c) h~t



(d) P~v



(e) u~v



9.3) Given, mixture of saturated water and saturated steam.

$m_f = 0.1\,Kg$ and $m_g = 0.9\,Kg$

(a) Pressure 14 bar

$H_f = 830.1\ KJ/Kg$ and $H_g = 2787.8\ KJ/Kg$

than $H = H_f m_f + H_g m_g$

$= 83.01 + 2509.06$

$= 2592.12\ KJ/Kg$

Also $u_f = 0.0011489\ m^3/Kg$

and $u_g = 0.14073\ m^3/Kg$

$v = m_f v_f + m_g v_g$

$= 0.12677\ m^3/Kg$

Therefor $u = H - Pv$

$= 2582.0 - 1.4 \times 10 \times 0.12677$

$= 2414.5\ KJ/Kg$

-Ans

(b) Temperature (t) = 250°C

$v_f = 0.00125\ m^3/Kg$ $v_g = 0.050037\ m^3/Kg$

$V = 0.045158\ m^3/Kg$

$h_f = 1085.8\ KJ/Kg$

$h_g = 2800.4\ KJ/Kg$

$H = 2628.94\ KJ/Kg$

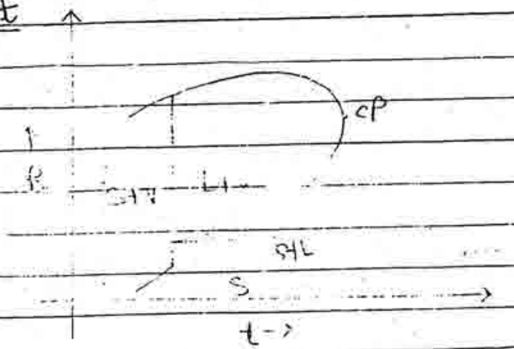
$u = H - Pv$

$= 2628.94 - 39.776 \times 10^3 \times 0.045158$

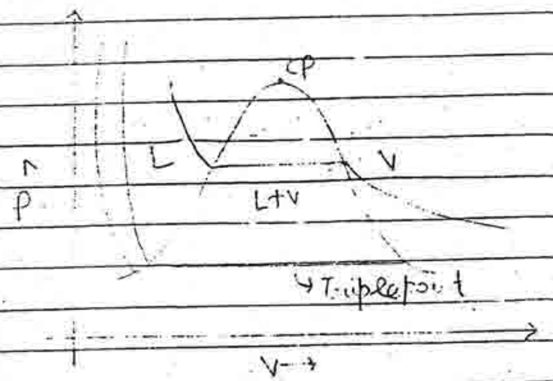
$= 2449.31\ KJ/Kg$

-Ans

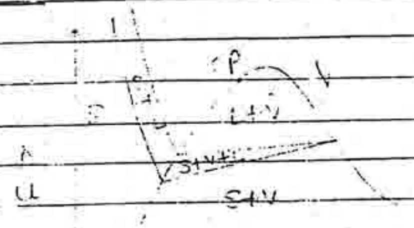
(c) $h \sim t$



(d) $P \sim v$



(e) $u \sim v$



9.3) Given, mixture of saturated water and saturated steam.

$m_f = 0.1\,Kg$ and $m_g = 0.9\,Kg$

(a) Pressure 14 bar

$H_f = 830.1\,KJ/Kg$ and $H_g = 2787.8\,KJ/Kg$

than $H = H_f m_f + H_g m_g$

$= 83.01 + 2509.06$

$= 2592.12\,KJ/Kg$

Also $v_f = 0.0011489\,m^3/Kg$

and $v_g = 0.14073\,m^3/Kg$

$v = m_f v_f + m_g v_g$

$= 0.12677\,m^3/Kg$

Therefor $u = H - Pv$

$= 2820 - 1.4 \times 10 \times 0.12677$

$= 2414.5\,KJ/Kg$

-Ans

(b) Temperature $(t) = 250^\circ C$

$v_f = 0.00125\,m^3/Kg$ $v_g = 0.050037\,m^3/Kg$

$V = 0.045158\,m^3/Kg$

$h_f = 1085.8\,KJ/Kg$

$h_g = 2800.4\,KJ/Kg$

$H = 2628.94\,KJ/Kg$

$u = H - Pv$

$= 2628.94 - 39.776 \times 10^3 \times 0.045158$

$= 2449.31\,KJ/Kg$

-Ans

$h_f = 1037.6$

$h_g = 2802.2$

9.4) Given, volume $= 0.04\,m^3$

$t = 240°C$, $m_f = 8\,kg$

at 240°C

$v_f = 0.0012291\ m^3/kg$

$v_g = 0.059645\ m^3/kg$

$V = m_f v_f + m_g v_g$

$0.04 = 8 \times 0.0012291 + m_g \times 0.059645$

$\Rightarrow m_g = \frac{0.0301672}{0.059645} = 0.505$

Total mass $m = m_f + m_g = 8 + 0.505$
$= 8.505\ kg$

Specific volume of mixture $= \frac{0.04}{m_g + m_f} = \frac{0.04}{8.505}$
$= 0.004702\ m^3/kg$

at $t = 240°C$ from steam table-

$h_f = 1037.6\ KJ/kg$ $\quad h_g = 2802.2\ KJ/kg$

$H = m_g h_g + m_f h_f$
$= 8 \times 1037.6 + 0.505 \times 2802.2$
$= 9718.7\ KJ/kg$

$H = U + PV$

$U = H - PV$
$= 9718.7 - \cancel{9718.7}(3.3478 \times 10^3 \times 0.0047021$
$= 9702.96\ KJ/kg$

- Ans

9.5) Given $t = 160°C$ $\quad x = 0.94$

$v_g = 0.1\,m^3$

at $t = 160°$ $v_f = 0.0011022$

$0.94 = \frac{m_g}{m_g + m_f}$

$\Rightarrow 0.94 m_g + 0.94 m_f = m_g$

$\Rightarrow 0.94 m_f = 0.04 m_g$

$V_g = m_g \times v_g$

$\Rightarrow 0.1 = m_g \times 0.30676$

$m_g = 0.32599\ kg$

Therefore $m_f = 0.01387\ kg$

$m = m_g + m_f = 0.32599 + 0.01387$
$= 0.339861\ kg$

Again at $t = 160°C$ $\quad H_f = 675.5\ KJ/kg$

$H_g = 2756.7\ KJ/kg$

$H = H_g m_g + H_f m_f$
$= 675.5 \times 0.01387 + 2756.7 \times 0.32599$
$= 908.02\ KJ/kg$

$H = u + PV$

$u = H - PV_{\times 10^3}$
$= 908.02 - 6.18 \times 10^5 \times 0$
$= 850.19\ KJ/kg$

- Ans

(b) $t_2 = 250°$ $\quad P = 6.1806\ bar = 6.1808 \times 10^5\ Nm^{-2}$

From superheated tables.

$P_1 = 6\,bar$ and $P_2 = 7\,bar$

$h_1 = 2951.6\ KJ/kg$ and $h_2 = 2954.6\ KJ/kg$

$h = h_1 + \left(\frac{h_2 - h_2}{P_2 - P_1}\right) \times (P - P_1) = 2952.14\ KJ/kg$

$H = h \times m$

$= 2952.14 \times 0.347\ KJ = 1024.4\ KJ$.

$\Delta H = 1024.4 - 913 = 112.4\ KJ$.

$v_2 = -\frac{0.39391-0.3367}{1} \times 0.1806 + 0.39391$

$= 0.36352\ m^3/Kg$

$V_2 = v_2 \times m$

$= 0.133\ m^3$

$H_2 = U_2 + PV_2$

or $U_2 = H_2 - PV_2$

$= 1024.4 - 6.1806 \times 10^5 \times 0.133 \times 10^{-3}$

$= 942.19\ KJ.$

$\Delta U = 942.19 - 851 = 92\ KJ$

Also, $dQ = dh = 112.4\ KJ$

$dQ = \Delta U + W$

$W = 112.4 - 92 = 20.4\ KJ.$

-Ans

9.6) (a) Given $V = 0.58\ m^3$ $m_s = 1\ Kg$

$P = 300 \times 10^3\ N/m^2 = 3\ bar$

From steam table $t = 133.54°C$

$v = \frac{0.58}{1} = 0.58\ m^3/Kg$

At 3 bar $v_f = 0.0010735\ m^3/Kg$

$v_g = 0.60553\ m^3/Kg$

$\therefore v = x \times 0.60553 + (1-x) \times 0.0010735$

$0.58 = x \times 0.6044565 + 0.0010735$

or $x = 0.958$

Again from steam table at 3 bar

$H_f = 561.4\ KJ/Kg$ and $H_g = 2724.7\ KJ/Kg$

$\therefore H = x H_g + (1-x) H_f$

$\Rightarrow H = 0.958 \times 2724.7 + 0.042 \times 561.4$

$= 2633.84\ KJ/Kg$

At 3 bar

$U_g = 2543.0\ KJ/Kg$ $U_f = 561.6\ KJ/Kg$

$U = 0.958 \times 2543.0 + 0.042 \times 561.6$

$= 2459.78\ m^3/Kg$

-Ans

(b) $t_2 = 160°C$ $v = 0.58\ m^3/Kg$

$P_1 = 3\ bar$ $v_1 = 0.65626\ m^3/Kg$ ✓

$P_2 = 4\ bar$ $v_2 = 0.48338\ m^3/Kg$

$\therefore$ Pressure at $v = 0.58\ m^3/Kg$ is-

$\therefore P$ (by interpolation) $= 3 + \frac{(0.65026 - 0.58) \times 1}{0.65026 - 0.48338}$

$= 3.421\ bar = 342.1\ KN/m^2$

At 160°C

$P_1 = 3\ bar$ $h_1 = 2781.4\ KJ/Kg$

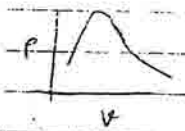
$P_2 = 4\ bar$ $h_2 = 2773.6\ KJ/Kg$

Enthalpy at 3.421 bar.

$h = 2781.4 + \frac{(3.421-3)}{(4-3)} \times (2773.6 - 2781.4)$

$\therefore h = 2778.2\ KJ/Kg$

$\therefore \Delta h = 144.5\ KJ/Kg$



$H = U + PV$

and $U_2 = 2778.2 - 342.1 \times 0.58$

$= 2579.8\ KJ/Kg$

$\therefore \Delta U = 2579.8 - 2459.7$

$= 120.1\ KJ/Kg$

From I[st] law of thermodynamics

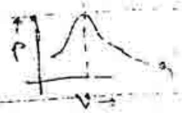
$Q - \cancel{W}^{0} = \Delta U$

$Q = \Delta U$

$= 120.1\ KJ/Kg$

-Ans

9.7)



Given $m = 1\,Kg$ (mixture of saturated steam and water)

$P = 140 \times 10^3\ N/m^2 = 1.4\ bar$

On heating the mixture passes through the critical point.

(a) At 1.4 bar

$V = V_g + V_f$

$V_g = m_g v_g$ $\qquad$ $V_f = m_f v_g$

$= m_g \times 1.2363$ $\qquad$ $= m_f \times 0.0010513$

$V = m_f \times 0.0010513 + m_g \times 1.2363$ —— ①

Also at critical point where $P = 221.20$ bar

$v_g = v_f = 0.003170\ m^3/Kg$

$\therefore V = (m_g + m_f) \times 0.003170$

$\Rightarrow V = 0.003170\ m^3$ —— ②

-Ans

(b) From ① and ②

$0.003170 = m_f\,(0.0010513) + m_g\,(1.2363)$

$= (1 - m_g)(0.0010513) + m_g\,(1.2363)$

$\Rightarrow m_g = 0.001715\ Kg$

and $m_f = 0.99828\ Kg$ -Ans

(c) $P = 300$ bar

At 300 bar the steam is superheated.

From steam tables of superheated steam –

at $400°c \Rightarrow v = 0.0028306\ m^3/Kg$

at $500°c \Rightarrow v = 0.0086808\ m^3/Kg$

Also here is a rigid vessel, therefore volume remains constant i.e. $0.003170\ m^3$

By interpolation

$0.003170 = 0.0028306 + \left(\frac{t - 400}{100}\right) \times 0.0058502$

$\Rightarrow t = 405.80°c$

-Ans

(d) at 1.4 bar

$H_1 = m_f h_{f_1} + m_g h_{g_1}$

$= 0.99828 \times [illegible]58.4 + 0.001715 \times 2690.3\ KJ$

$= 462.225\ KJ/Kg$

at 300 bar

$H_2 = m_f h_{f_2} + m_g h_{g_2}$

at $400°C \Rightarrow H_2' = 2161.8\ KJ/Kg$

at $500°C \Rightarrow H_2'' = 3035.0\ KJ/Kg$

at 405.8°C –

$H_2 = 2161.8 + \left(\frac{5.8}{100}\right)(923.2)$

$= 2215.35\ KJ/Kg$

$U_2 = 2215.35 - 300 \times 10^2 \times 0.0013170$

$= (2120.25 - 461.25)\ KJ/Kg$

From Ist law of thermodynamics –

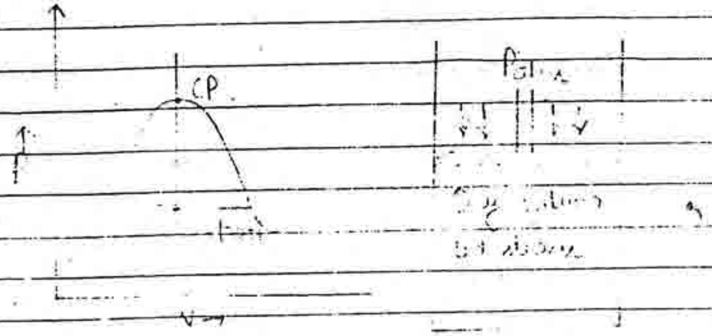
$dQ - \cancel{dW}^{0} = dU$

$dQ = dU$

$dQ = U_2 - U_1 = \Delta U = 1658.46\ KJ/Kg$ [illegible]

-Ans

9.8)



Given - mass of dry saturated steam = 0.03 Kg

$P_i = 3$ bar

Pressure of saturated water introduced = 3 bar

at 3 bar -

$V_g = m_g \times v_g = 0.03 \times 0.60553$

$= 0.0181659\ m^3$

$V_f = m_f \times v_f = m_f \times 0.0010735$

$\therefore V = V_g + V_f$

$= 0.0181659 + m_f \times 0.0010735$ —(1)

Also, at critical point -

$V = m_g v_g + m_f v_f$

$= 0.003170(m_g + m_f) = 0.003170 \times (0.03 + m_f)$

But the volume remains same throughout.

$\therefore 0.0181659 + m_f \times 0.0010735 = 0.003170\,(0.03 + m_f)$

$\Rightarrow 0.0020965\, m_f = 0.0180708$

$\Rightarrow m_f = \dfrac{0.0180708}{0.0020965}$

$= 8.61$ Kg

Mass of saturated water added is 8.61 Kg

-Ans

9.9) Given, Pressure of boiler = 8 bar (P_1)

$P_2 = 1$ bar

Temperature (t_2) = 116°c

The enthalpy of the steam before entering into the throttling calorimeter; x be its dryness factor (H_1) is given as (H_1) at 8 bar

$H_1 = x h_g + (1-x) h_f$

$= x \times 2767.5 + (1-x) \times 720.9$ —(1)

At pressure (P_2) = 1 bar ; the saturated temp. is 99.63°c

But the temp. here is 116°C; therefore the steam obtained from T.C. is superheated. Its enthalpy would be H_2.

at 100°c $H_2' = 2676.2$ KJ/Kg

at 150°c $H_2'' = 2776.3$ KJ/Kg

By interpolation at t = 116°C

$H_2 = H_2' + \dfrac{(t-100)}{150-100}(H_2'' - H_2')$

$= 2676.2 + \dfrac{16}{50}(2776.3 - 2676.2)$

$H_2 = 2708.17$ KJ/Kg

But the enthalpy of steam remains the same

therefore $H_1 = H_2$

From (1) and (2)-

$2708.17 = x \times 2767.5 + (1-x) \times 720.9$

$1987.27 = x \times 2046.6$

$x = 0.971$

-Ans

9.10) Given, main pressure = 34 bar (Gauge)

Mass of water attained from separator = 0.33 kg

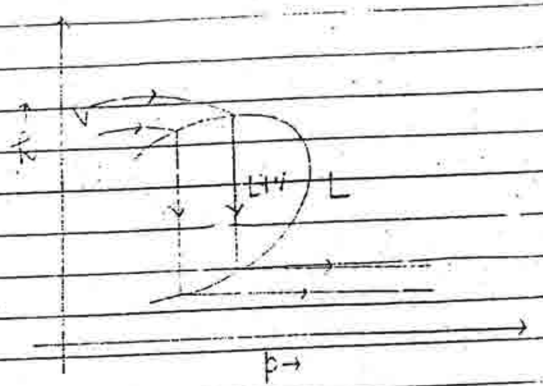
Mass of steam condensed after passing through the nozzle throttle = 4.66 Kg

Throttling calorimeter readings

Pressure:- 51 mm of water (Gauge)

Temperature = 145°C

Barometer reading = 746 mm of Hg



Atm pressure $= \frac{746 \times 13600 \times 9.81}{1000}$

$= 0.99$ bar $\simeq 1$ bar

Main pressure (absolute) = 35 bar

$P_2 = \frac{51}{1000} \times 1000 \times 9.81 \approx 0.005$ bar

Mass of water obtained from calorimeter = 0.33 kg (m_f)

Mass of steam (m_g) = 4.66 kg

Dryness fraction of steam leaving calorimeter

$x_1 = \frac{m_g}{m_g + m_f} = \frac{4.66}{4.66 + 0.33}$

$= 0.933$

Also, $H_1 = H_2$ (at 1 bar and 145°C)

At 1 bar and 100°C (H_2') = 2676.2 KJ/Kg

At 1 bar and 150°C (H_2'') = 2776.3 KJ/Kg

H_2 (by interpolation) :: $2676.2 + \frac{45}{100}(100.1)$

$= 2766.29$ KJ/Kg

and $H_1 = H_{f1} + x_2 H_{fg}$

$= 1049.7 + x_2 \times 1752.2 = 2766.29$

$1049.7 + 1752.2 x_2 = 2766.29$

$\Rightarrow x_2 = 0.977$

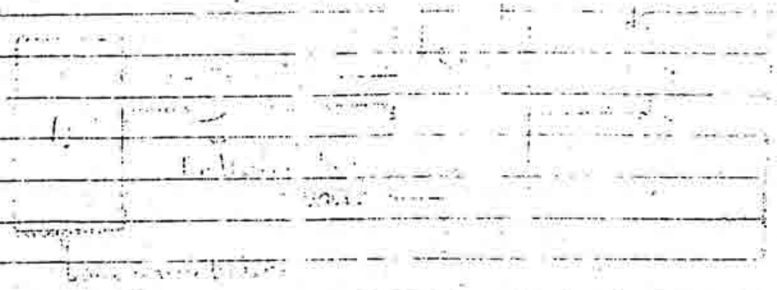
$x_{main} = x_1 \times x_2$

$= 0.977 \times 0.933$

$= 0.914$

—Ans

9.11)



Given $m_g = 0.007$ Kg/s

$I = 3.78$ Amp $V = 230$ V

$P_1 = 4$ bar $P_2 = 2$ bar $t_2 = 155°C$

At $P = 2$ bar $t = 120°C$

steam is superheated

$t_1' = 150°C$ $t_2' = 200°C$ $t_2 = 155°C$

$h_1' = 2768.5$ KJ/Kg $h_2' = 2870.5$ KJ/Kg

by interpolation

$h_2 = h_1' + \frac{(h_2' - h_1')}{} \times \left(\frac{t_2 - t_1'}{t_2' - t_1'}\right)$

$= 2778.7$ KJ/Kg

$H_2 = h_2 \cdot m_{ff} = 2778.7$ KJ/Kg $\times 0.007$ Kg

$= 19450.9$ J/s

Now $H_1 = H_2$ - internal energy of the heater coil

Internal energy of wet steam = Work done by coil

$= V \times I = 230 \times 3.73$

$= 869.4$ J/s

Internal energy of heater coil $= 869.4$ J/s

$H_1 = 19450.9 - 869.4 = 18581.5$ J/s

$h_1 = \frac{18581.5}{0.007} = 2654.5$ KJ/Kg

At 4 bar $h_g = 2737.6$ KJ/Kg

$\therefore h_1 < h_g$ some steam is wet.

$\therefore h_1 = h_f + x h_{fg}$

$\Rightarrow 2654.5 = 604.7 + x \times 2132.9$

$\Rightarrow x = 0.961$

-Ans

9.12) Given

Diameter of cylinder

$= 280$ mm

Mass of steam

$= 0.02$ Kg

Pressure (P_1)

$= 6$ bar

$L = 305$ mm

$P_2 = 1.2$ bar

$\frac{v_c}{v_1} = 0.35204\ m^3/Kg$ (from steam tables)

$\therefore \frac{v_c}{v_1} = 0.35204 \times 0.02$

$= 0.0070408\ m^3$

Also $V_{sw} = \frac{\pi}{4} d^2 \times L$

$= \frac{\pi}{4} \times (0.280)^2 \times 0.305 = 0.01877\ m^3$

$V_L = 0.025812\ m^3$ ($V_L = V_c + V_{sw}$)

(a) PV^n = constant

$P_1 V_1^n = P_2 V_2^n$

$6 \times (0.0070408)^n = 1.8 \times (0.025812)^n$

$5 = (3.6606)^n$

$n = \frac{\ln 5}{\ln(3.6606)} = 1.2388 \approx 1.24$

-Ans

(b) Work done (W) $= \frac{P_2 V_2 - P_1 V_1}{1-n}$

$= \frac{10^5 (1.2 \times 0.025812 - 6 \times 0.0070408)}{-0.24}$

$= 0.04695 \times 10^5$

$= 4.696 \times 10^3$ J $= 4.696$ KJ

-Ans

(c) $\frac{V_L}{0.02} = v = v_{f_2} + x_2 v_{fg_2}$

$1.2906 = 0.0010476 + x_2 \times 1.4270524$

$\therefore x_2 = 0.903$

Also $H_2 = H_{f_2} + x_2 H_{fg_2}$

$= 439.4 + 0.903 \times 2244.1$

$= 2465.32$

$U_2 = 2465.82 - 1.2 \times 10^6 \times 0.025812$

$= 2462.72$ KJ/kg

$\Delta U = U_2 - U_1$

$= (2462.72 - 2845.47) \text{ KJ/Kg}$

$= -7.655$

By I^{st} law –

$Q - W = \Delta U$

$Q = \Delta U + W$

$= -7.655 + 4.656 = -2.959 \text{ KJ}$

– Ans

9.13) Given,

$m_g = 1 \text{ kg}$

$P_1 = 1 \times 10^6 \text{ N/m}^2$

$= 10 \text{ bar}, t_1 = 250°C$

$P_2 = 2 \times 10^6 \text{ N/m}^2 = 20 \text{ bar}$

$W = -610 \times 10^3 \text{ N-m}$

$= -610 \text{ KJ}$

$Q = -890 \times 10^3 \text{ J} = -890 \text{ KJ}$

From superheated table –

$h_1 = 2943.0 \text{ KJ/Kg}$

From I^{st} law –

$\Delta U = Q - W$

$m(h_2 - h_1) = Q - W$

$1(h_2 - 2943.0) = -870 + 610$

$\therefore h_2 = 2663 \text{ KJ/Kg}$

At $P_2 = 20$ bar $\quad h_g = 2797.2 \text{ KJ/Kg}$

$h_2 < h_g$; so the steam is wet saturated.

$h_2 = h_f + x h_{fg_2}$

At $P_2 = 20$ bar,

$h_f = 908.6 \text{ KJ/kg}$ and $h_{fg} = 1888.7 \text{ KJ/kg}$

$2663 = 908.6 + x(1888.7)$

$\Rightarrow x = 0.92$

– Ans

9.14) Given $t_1 = 80°C$ and $t_2 = 65°C$

(a) Specific heat $c_p = 4.19 \times 10^3 \text{ J/kg K}$

$Q = m c_p \Delta t$

$q = c_p \Delta t = 4.19 \times 10^3 \times 65 - 80$

$= -62.85 \text{ KJ/Kg}$

– Ans

(b) At $t_1 = 80°C \quad h_{f_1} = 334.9 \text{ KJ/Kg}$

At $t_2 = 65°C \quad h_{f_2} = 272.0 \text{ KJ/Kg}$

$\Delta U = m(h_{f_2} - h_{f_1})$

$q = h_{f_2} - h_{f_1}$

$= 272.0 - 334.9 = -62.9 \text{ KJ/kg}$

– Ans

9.15) Given $V = 60$ m/s $\quad P_1 = 8$ bar

$T = 79.6$ K superheat)

$P_2 = 160 \times 10^3 \text{ N/m}^2 = 1.6 \text{ bar}$

$x = 0.96$ and $A_2 = 12 \text{ cm}^2$

$Q = 0$ (Adiabatic process)

(a) $t_1 =$ Saturation temp at 8 bar + 79.6

$= 170.4 + 79.6 = 250.0°C$

From superheated table, $h = 2950.4 \text{ KJ/Kg}$

From S.F.E.E.

$$\frac{Q - W_x}{m} = h_2 - h_1 + \frac{V_2^2}{2g_c} - \frac{V_1^2}{2g_c}$$

$$h_2 - h_1 + \frac{V_2^2}{2g_c} - \frac{V_1^2}{2g_c} = 0$$

at $P_2 = 1.6$ bar

$h_2 = h_f + x h_{fg_2}$

$= 475.4 + 0.96 \times 2220.9$

$= 2607.464 \text{ KJ/Kg}$

$\therefore (2607.464-2950.4) + \frac{v_2^2}{2} - \frac{60^2}{2} = 0$

$v_2^2 = 685472$

$\therefore v_2 = 830\,ms^{-1}$

$v_1 = v_{f_1} + x v_{fg_1}$

$= 0.0010546 + 0.96(1.091 - 0.0010645)$

$= 1.04750\,m^3/Kg$

$m = \frac{A_2 V_2}{v_1} = \frac{12\times10^{-4}\times830}{1.04750} = 0.951\,Kg/s.$

-Ans

(b) Temp. of exhausted water from condenser $t = 95°C$

Initial temp. of cooling water $= 10°C$

Final temp. of cooling water $= 25°C$

$m = 0.951\,Kg/s$

By SFEE-

$\cancel{Q}^{0} - \cancel{W}^{0} = \Delta m\left(\Delta h + \frac{V^2}{2g_c} + \cancel{\frac{gz}{g_c}}\right)^0$

$m_1(h_3 - h_2) + m_1\left(\frac{V_3^2 - V_2^2}{2g_c}\right) + m_c(h_5 - h_i) = 0$

$0.951(398 - 2607.46)\times10^3 - 0.951\frac{(830)^2}{2\times1} + m_c(104.8 - 42)\times10^3 = 0$

$\Rightarrow m_c = 38.8\,Kg/s.$

-Ans

9.16) Given $P_1 = 2\times10^6\,N/m^2$ $t_1 = 250°C$

$h_1 = 2902.4\,KJ/Kg.$

$P_2 = 15\times10^3\,N/m^2$ $V_2 = 20\,ms^{-1}$

Heat transfer rate to atm $(q) = 160\times10^3\,W$

Power delivered by turbine $W = 3430\times10^3\,W$

$m = 6.1\,Kg/s$

By S.F.E.E.

$\frac{Q - W_x}{m} = h_2 - h_1 + \frac{V_2^2 - V_1^2}{2g_c} \to 0$

$\Rightarrow \left(\frac{-160\times10^3 - 3430\times10^3}{6.1}\right) = h_2 - 2902.4\times10^3 + \frac{(20)^2}{2}$

$h_2 = \frac{3590\times10^3}{6.1} - 2882.4\times10^3$

$h_2 = 2293.87\,KJ/Kg.$

$h_2 = h_{f_2} + h_{fg_2}$

at $P_2 = 0.15\,bar$ $h_{f_2} = 226.0\,KJ/Kg.$

$h_{fg_2} = 2373.2\,KJ/Kg$

$2293.87 = 226.0 + x(2373.2)$

$\Rightarrow x = 0.871$

$v_2 = v_{f_2} + x v_{fg_2}$

At $P_2 = 0.15\,bar$ $v_{f_2} = 0.001014\,m^3/Kg$

$v_{fg_2} = 10.020980\,m^3/Kg.$

$v_2 = 0.001014 + 0.871\times10.020980$

$= 8.729282\,m^3/Kg$

$m = \frac{A_2 V_2}{v_2} \Rightarrow A_2 = \frac{m v_2}{V_2}$

$= \frac{6.1\times8.729292}{200}$

$\therefore A_2 = 0.266\,m^2$

-Ans

Coff. of performance $= \dfrac{Q_2}{W}$

[CHAPTER-10]

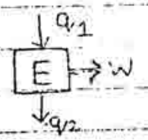
[THE SECOND LAW OF THERMODYNAMICS]

10.1) Given, $W = 21.5 \times 10^3$ N-m

$Q_1 = 90 \times 10^3$ J

$\eta = \dfrac{W}{q_1} = \dfrac{21.5 \times 10^3}{90 \times 10^3} = 0.239$

Efficiency of engine $= 23.9\%$



$W = q_1 - q_2$

$q_2 = q_1 - W$

$= 90 \times 10^3 - 21.5 \times 10^3$

$= 68.5$ KJ

-Ans

10.2) Given efficiency $= 20\%$

$\eta = 0.2$

$W = 100$ KW

$\eta = \dfrac{W}{q_1} \Rightarrow q_1 = \dfrac{W}{\eta}$

$q_1 = \dfrac{100 \times 10^3}{0.2} = 500$ KW

$W = q_1 - q_2$

$q_2 = q_1 - W$

$= 500 - 100 = 400$ KW

-Ans

10.3) Given $\eta = 1 - \dfrac{1}{r^{\gamma - 1}}$

(a) $r = 7$ and $\gamma = 1.4$

$\eta = 1 - \dfrac{1}{7^{0.4}} = 0.547$

$\Rightarrow$ Efficiency $= 54.1\%$

-Ans

(b) $q_2 = 3.2 \times 10^6$ J/s

$\eta = \dfrac{W}{q_1} = \dfrac{q_1 - q_2}{q_1}$

$\Rightarrow q_1 - q_2 = \eta q_1$

$\Rightarrow q_2 = (1-\eta) q_1$

$\Rightarrow q_1 = \dfrac{q_2}{(1-\eta)}$

$= \dfrac{3.2 \times 10^6}{1 - 0.541} = 6.969 \times 10^6$ J/s

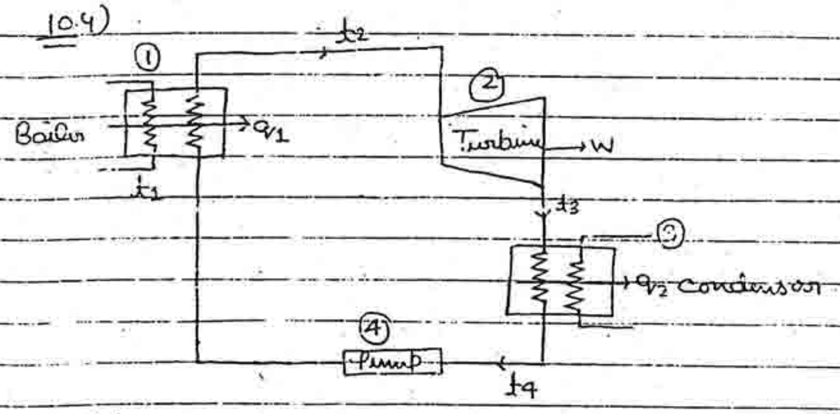
$q_1 = 6969$ kW

$W = q_1 - q_2$

$= 6969 - 3200 = 3768$ kW

-Ans

10.4)



Given,

Boiler $P_1 = 7$ bar

$t_2 = 200°C$

Feed water $t_1 = 55°C$

$m_s = 0.0262$ kg/s

Engine shaft power = 6.5 KW

Condensor : $\dot{m}_3 = 0.73$ Kg/s $t = 151°C$

$$q = \frac{Q}{m}$$

(a) By S.F.E.E.

$$\frac{Q-\cancel{W}^{0}}{m} = \Delta H + \cancel{\frac{V^2}{2g_c}}^{0} + \cancel{\frac{gz}{g_c}}^{0}$$

$$\Rightarrow \frac{Q}{m} = \Delta h$$

$$\Rightarrow \boxed{q_1 = h_2 - h_1}$$ (From Steam table)

at 7 bar – $t = 200°C$ and $h_2 = 2844.2$ KJ/Kg

$t_1 = 55°C$ and $h_1 = 230.2$ KJ/Kg

$\therefore q_1 = (2844.2 - 230.2)$?

$= 2614$ KJ/Kg

– Ans

(b) $\boxed{w = \frac{\text{Shaft Power}}{\text{Mass of flow rate}}}$

$$= \frac{6.5\times10^3}{0.0262} = 248.1 \text{ KJ/Kg}$$

– Ans

(c) Temperature of steam at inlet of condensor,

$\underline{t_3 = 200°C}$ (473 – 19) K

Temperature of water at outlet (t_4) = ~~200+19~~

= 181°C

Enthalpy of inlet steam (h_3) = $h_2 - w$ = 2844.2 – 248.1

= 2596.1 KJ/Kg

ΔH for Δt = 19 K

ΔH = 79.6 KJ/Kg ← ?

Q = 0.0262 (h_4 – 2596.1) + 0.73 × 79.6

h_4 = 378.2 KJ/Kg

flow rate × Δh

Heat trans for from system = $h_3 - h_4$

= 2596.1 – 378.2

= 2217.9 KJ/Kg

– Ans

(d) Heat tran for to atmosphere = $h_4 - h_f$

= 378.2 – 230.2

= 148 KJ/Kg

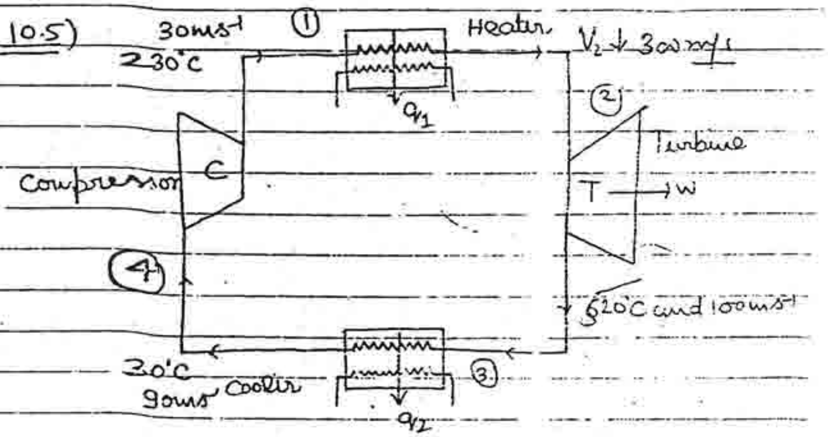
– Ans

(e) $\eta = \frac{W}{q_1} = \frac{248.1}{2614} = 0.0949$

Efficiency = 9.49%

– Ans

10.5)



Given, 30°C

$t_{3\to4} = 3°C$ $V_{3\to4} = 90$ ms⁻¹

$t_{4\to1} = 230°C$ $V_{4\to1} = 30$ ms⁻¹

$t_{2\to3} = 520°C$ $V_{2\to3} = 100$ ms⁻¹

$V_2 = 300$ ms⁻¹

$q_1 = 642$ KJ/Kg

h of entering st...

Δh (for $\Delta t = 19K$) = 79...

$\therefore$ By S.F.E.E.;

$0 = 0.0262(h - 2596.1) + 0.73(79.7)$

$\Rightarrow h = 375.5$ kJ/kg

$\therefore$ Heat transfer from system $= 2596.1 - 375.5$

$= 2220.6$ kJ/kg Ans

(d) Heat transfer to the atmosphere

$= h$(of water from condenser) $- h$(of entering water)

$= 375.5 - 230.2$

$= 145.3$ kJ/kg

(e) $\eta = \frac{W}{Q_1} = \frac{248.1}{2614} = 0.0949 \times 100\% = 9.49\%$

Ans 15.5:

$C_p(air) = 1.005$ kJ/kg K

(a) From heater, using SFEE;

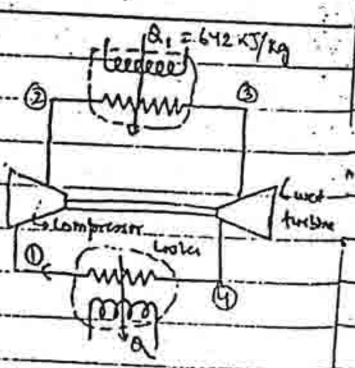
$\frac{Q - \cancel{W}^0}{m} = \Delta h + \cancel{\Delta PE}^0 + \Delta K.E$

$C(\Delta t) = \Delta h$

$\Rightarrow 64200 = 1005[t_3 - (230+273)] + \frac{(9 - 0.09)}{2} \times 10^4$

$t_3 = 1097.47$ K

$= 824.47$ °C Ans



(b) The heat transfer from the air ... the water i...

$\frac{Q - \cancel{W}^0}{m} = \Delta[h + \frac{V^2}{2}...]$

... = ... kJ/kg

(c) Net work output of the plant is

$W = Q_1 - Q_2 = 624 - 493.4$

$= 148.6$ kJ/kg

(d) Efficiency, $\eta = \frac{W}{Q_1} = \frac{148.6}{642} = 0.2314$

$\Rightarrow \eta = 23.14\%$

Ans 15.7:

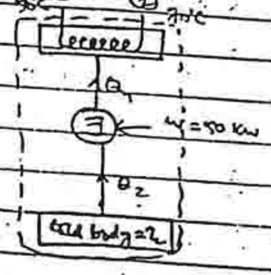
(a) $COP_c = 5 = \frac{Q_2}{W}$

$\Rightarrow Q_2 = 5 \times 50 \times 1000 = 250$ kJ

also; $W = Q_1 - Q_2$

$\Rightarrow Q_1 = W + Q_2$

$\Rightarrow Q_1 = 300$ kJ



(b) by S.F.E.E;

$\frac{Q - \cancel{W}}{m} = \Delta h + \cancel{\Delta PE}^0 + \cancel{\Delta KE}^0$

$\Rightarrow h_2 - h_1 = \frac{300}{m}$

h_2 (at 70°C) $= 293$ kJ/kg

h_1 (at 50°C) $= 209.3$ kJ/kg

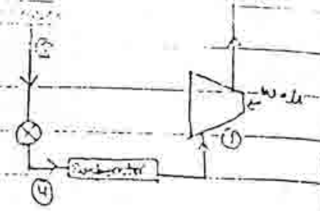
$\Rightarrow m = \frac{300}{293 - 209.3}$

$= 3.58$ kg/s

Q. 10.9

$h_1 = 199.6 \times 10^3$ J/kg

$h_3 = 64.6 \times 10^3$ J/kg



(a) $\Delta h = 135 \times 10^3$ J/kg

$Q = 1.5 \times 10^3$ J/s

By S.F.E.E. ; $Q = m[\Delta h + \Delta PE + \Delta KE]$

$\Rightarrow m = \frac{1.5 \times 10^3}{135 \times 10^3} = 11.1 \times 10^{-3}$ kg/s Ans

(b) $Q_{condenser} = W_{compressor} + Q_{evaporator}$

$\Rightarrow Q_{ev} = Q_{cond} - W_{comp}$

$\Rightarrow Q_{ev} = 1500 - 310$

$= 1190$ J/s

(c) $\Delta Q = 0;\ \Delta W = 0 \Rightarrow \Delta U = 0$

$h_4 = h_3 = 64.6$ kJ/kg

(d) $h_4 = h_f + x h_{fg}$

$\Rightarrow 64.6 = 22.3 + x(181 - 22.3)$

$\Rightarrow x = 0.266$

$\frac{Q_{ev}}{m} = \cancel{1500 - 310}\ \ h_1 - h_4 = 1.19$ kJ/s

$\therefore \Rightarrow h_1 = 1.19 + 0.717 = 1.907$ kJ/kg

$\Rightarrow h_1 = \frac{1.907}{11.1 \times 10^{-3}} = 171.8$ kJ/kg

$171.8 = 22.3 + x(181 - 22.3)$

$\Rightarrow x = 0.942$ Ans

(e) $COP_h = \frac{Q_{ev}}{W} = \frac{1190}{310} = 3.84$ Ans

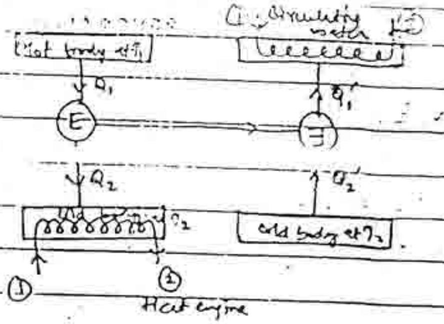
$\frac{Q_{ev}}{m} = \frac{1.19}{11.1 \times 10^{-3}} = h_1 - h_4$

$\frac{1.19}{11.1 \times 10^{-3}} + h_4 = h_1$

$\frac{1.19}{11.1 \times 10^{-3}} + 64.6 = h_1$

$\frac{1.19 + 0.717}{11.1 \times 10^{3}} = h_1$

10.10



$\eta = \frac{W}{Q_1} = 27\% = 0.27$

$\frac{Q_1'}{W} = 4$

$\frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$

But $\frac{W}{Q_1} = \eta$

$\therefore \eta = 1 - \frac{Q_2}{Q_1}$

$\Rightarrow \frac{Q_2}{Q_1} = 0.73$ —(1)

$\frac{Q_1'}{W} = 4$ —(2)

$\frac{W}{Q_1} = 0.27$ —(3)

(2) × (3) $= \frac{Q_1'}{Q_1} = 1.08$ —(4)

Adding (1) & (4)

$\frac{Q_1' + Q_2}{Q_1} = 1.08 + 0.73 = 1.81$

C – 11

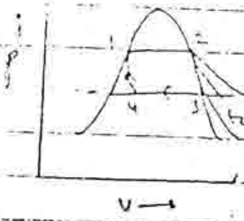
$Q = W + \Delta U$

$\boxed{Q = W + \Delta h}$

11.2 fluid = 1 kg water

hot body temp. = 200°C

cold body temp = 45°C



State I Saturated liquid at 200°C

S/p enthalpy ; $h_1 = 852.4$ kJ/kg

$P_1 = 15.549 \times 10^5$ N/m²

$v_1 = 0.0011565$ m³/kg

$u_1 = h_1 - p v_1$

$= 852.4 \times 10^3 - 15.549 \times 10^5 \times 0.0011565$

$= 850.60$ kJ/kg

State II By saturated vapour temp at 200°C

$h_2 = 2790.9$ kJ/kg

$v_2 = 0.12716$ m³/kg ; $P_2 = 15.549 \times 10^5$ N/m²

$u_2 = 2790.9 - 15.549 \times 10^3 \times 0.12716$

$= 2593.18$ kJ/kg

State III wet vapour, $x = 0.762$; $t = 45°C$

$h_3 = h_g - (1-x) h_{fg}$

$h_3 = 2574.4 - (1 - 0.762)(2574.4 - 167.5)$

$= 2001.56$ kJ/kg

$P_3 = 0.07375 \times 10^5$ N/m²

$v_3 = 19.546 - (1 - 0.762)(19.545) = 14.8943$ m³/kg

$u_3 = h_3 - P_3 v_3$

$= 2001.56 - (0.07375 \times 14.8943 \times 10^{-3})$

$= 1891.745$ kJ/kg

State IV ...

S/p enthalpy ; $h_4 = 2574.4 - (1 - 0.327)(2574.4 - 167.5)$

$= 718.68$ kJ/kg

$v_4 = 19.546 - (1 - 0.227)19.545$

$= 4.4772$ kJ/kg

$P_4 = 0.07375 \times 10^5$ N/m²

$u_4 = 718.68 - 4.4772 \times 0.07375 \times 10^5 \times 10^{-3}$

$= 685.67$ kJ/kg

$h = u + p\cancel{v}$ ∵ isobaric

∴ $\Delta Q = \Delta h = \Delta U$

Process 1 → 2 (Isothermal) ⇒ $\Delta Q = \Delta h$

$\Delta Q = \Delta h = 2790.9 - 852.4 = 1938.5$ kJ/kg Ans

$\Delta W = \Delta Q - \Delta U = 1938.5 - (2593.18 - 850.60)$

$= 195.92$ kJ/kg

Process 2 → 3 (adiabatic)

$\Delta Q = 0 \Rightarrow \Delta W + \Delta U = 0$ $\Delta W_R = -\Delta U$

$\Rightarrow \Delta W = u_2 - u_3 = 2593.18 - 1891.745$

$= 702.8$ kJ/kg

Process 3 → 4 (Isothermal) ⇒ $\Delta Q = \Delta h$

$\Delta Q = Q_4 - Q_3 = -1282.9$ kJ/kg

$\Delta U = u_4 - u_3 = 685.67 - 1891.745$

$= -1206.075$ kJ/kg

$\Delta W = \Delta Q - \Delta U = -1282.9 + 1206.075$

$= -81$ kJ/kg

Process 4 → 1 (adiabatic)

$\Delta Q = 0 \Rightarrow -\Delta U = +\Delta W$

$\Rightarrow \Delta W = u_4 - u_1 = 850.60 - 685.67$

$= -164.93$ kJ/kg

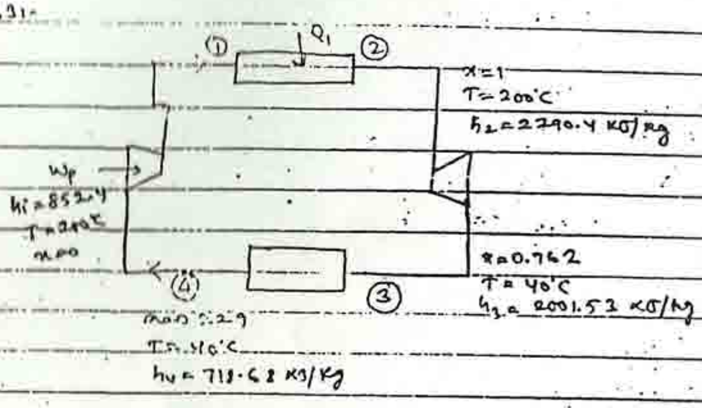
$193.524 - 722.6 - 51 = 164.93$

$.79\ KJ/Kg$

$\eta = \frac{\Sigma W}{\Sigma Q} \times 100 = \frac{657.79}{1938.5} = 0.339$

$\Rightarrow \eta = 33.9\ \%$

Ans 11.91-



For heater $1 \to 2$; $W=0$

$Q - W = \Delta h$

$\Rightarrow Q = 1938.5\ KJ/Kg$

for $2 \to 3$;

$Q = 0$

$Q - W = h_3 - h_2$

$W = 788.75\ KJ/Kg$

for $3 \to 4$; cooler

$W = 0$

$Q - W = h_4 - h_3$

$Q = -1282.??\ KJ/Kg$

$4 \to 1$ Compressor; $Q = 0$

$-W = 133.72 \Rightarrow W = -133.72\ KJ/Kg$

$\Sigma W = 654.53\ KJ/Kg$

$\eta = \frac{\Sigma W}{q_1 \cdot q_{in}} = 33.18\ \%$

Notes

CHAPTER - 12

THE ABSOLUTE TEMPERATURE SCALE

Ans 12.1

(a) $T_1 = 150°C = 150+273 = 423\ K$

$T_2 = 10°C = 10+273 = 283\ K$

$\eta_R = \frac{T_1 - T_2}{T_1} = \frac{423-283}{423} = 0.331$

$\eta_R = 33.1\%$

(b) also $\eta = \frac{W}{Q_1} \Rightarrow Q_1 = \frac{2000}{0.331} = 6.04\ KJ$

$W = Q_1 - Q_2 \Rightarrow Q_2 = 6.04 - 2 = 4.04\ KJ$

(c) $COP_{H} = \frac{Q_1}{W} = \frac{6.04}{2} = 3.02$

$COP_R = 3.02 - 1 = 2.02$

also $COP_R = \frac{Q_2}{W}$

$\Rightarrow W = \frac{40}{2.02} = 19.8\ KW$

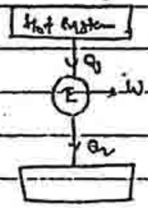
Ans 12.2

$T_1 - T_2 = 60\ K$

$W = 0.2 Q_2$

$\therefore Q_1 - Q_2 = 0.2 Q_2$

$\Rightarrow \frac{Q_1}{Q_2} = 1.2 = \frac{T_1}{T_2}$



$\Rightarrow T_1 = 1.2 T_2$

$\Rightarrow T_1 - T_2 = 60$

$\Rightarrow T_2 = \frac{60}{0.2} = 300K = 27°C$

$T_1 = 60+300 = 360K = 87°C$

$\eta = \frac{T_1 - T_2}{T_1} = \frac{60}{360} = 16.66\%$

12.6 ... KJ/kg ... = 30 KW

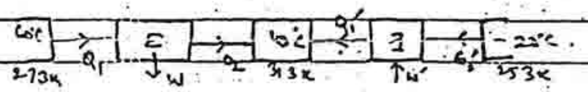
$\Rightarrow Q_1 = 30+10 = 40\ KW$

$COP_H = \frac{Q_1}{W} = \frac{40}{10} = 4$ Ans

(ii) Max Possible $COP_R = \frac{T_1}{T_1 - T_2} = \frac{293}{293-269} = 12.2$

$\therefore$ min power output $= \frac{40}{12.2} = 3.28$

12.7



(a) $W_E = W' = 350 \times 10^3\ Nm$ —(1)

$Q_1 = 2000\ KJ$

$\frac{W_E}{T_1 - T_2} = \frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

$\Rightarrow W_E = \frac{Q_1}{T_1}(T_1 - T_2) = \frac{2000}{873}(873-313) = 1282.93\ KJ$

from (1): $W = 1282.93 - 350 = 932.23\ KJ$

also; $Q_1' = \frac{W T_1'}{T_1' - T_2'} = \frac{932.23 \times 10^3}{313-253} \times 253$

$= 3933.85\ KJ$

$Q_2 = \frac{Q_1 T_2}{T_1} = Q_1 \times \frac{T_2}{T_1} = \frac{2000 \times 313}{873} = 717.07\ KJ$

and $Q_1' = \frac{Q_2'}{T_2} \cdot T_1 = \frac{3933.85}{253} \times 313 = 4866.78\ KJ$

Net heat transfer to 40°C $= Q_2 + Q_1' = 5583.85\ KJ$

(b) $\eta = \frac{40}{100} \times \frac{600-40}{873} = 0.2567$

and $COP = \frac{40}{100} \times \frac{253}{40+20} = 1.687$

Solved Example

From saturated steam tables, v_{fg}

h_{fg} over temp interval between 17.5 °C and 200 °C.

$$T = \frac{h_{fg}}{v_{fg}} \frac{\delta T}{\delta p}$$

$$\Rightarrow T = \frac{1948.3}{0.13285} \times \frac{5}{156.2 \times 10^3}$$

which is approximately the A.M. of 175 °C and 200 °C

∴ Good precision can be achieved by using small temp interval

∴ Table is self consistent in this region.

Solved Example 12.3

$T_1 = 80 + 273 = 353 K$

$T_2 = 0 + 273 = 273 K$

$$COP_R = \frac{1}{\eta_R} = \frac{353}{353-273} = 4.41$$

$$\text{Min power output} = \frac{90000}{4.41} \ KJ/kg$$

$$= \frac{90000}{4.41 \times 3600} \ KJ/s$$

$= 5.67$ KW. Ans.

$x = \frac{m_s}{m_s + m_w}$

$$x = \frac{0.7}{0.8} = 0.875$$

temp = 133.54 °C

$S = 1.6917 + 0.875 \times 5.3192 = 6.336$ KJ/kg K

(b) temp = 250 °C

$S = 6.97$ KJ/kg K

From saturated steam table

∴ s at 9 bar = 6.9288 KJ/kg K

s at 10 bar = 6.9259 KJ/kg K

∴ the temp at which entropy is 6.97 KJ/kg K

$$P = 9 + \left(\frac{6.98 + 6.97}{6.98 - 6.9258}\right) \times 1$$

$P = 9.185$ bar ⇒ 918.5 KN/m²

$P = 9.185$ bar ⇒ 918.5 KN/m²

$h = 2946.8 - (2946.8 - 2943.0) \times 0.185$

∴ $h = 2946.09$ KJ/kg

$v = 0.25963 - (0.25963 - 0.23275) \times 0.185$

$v = 0.25466$ m³/kg

$h = u + pv$

∴ $u = h - pv = 2712.2$ KJ/kg

This falls under saturated steam table at 250 °C

the P is 39.776 bar = 39.776×10^5 N/m²

$S = S_f + x S_{fg}$

$5.661 = 2.7935 + 3.2773x$

∴ $x = 0.875$

$v = v_f + x v_{fg}$

$= 0.001251 + 0.875 \times 0.048 = $ [illegible] m³/kg

$h = 1085.8 + 0.9755$

$\therefore U = 2411.38$ KJ/kg

Soln 13.6

$\Delta s = \frac{dQ}{T}$

$\therefore \Delta s = \frac{2046.5}{(170.41+273)}$

$\Delta S = 4.6140$ KJ/kg K

$P = 800\times10^3$ N/m²

increase in enthalpy

Expansion work

$W = 800\left(0.24026 - \frac{1115}{102}\right)$ KJ

$\therefore W = 191.32$ KJ

$Q = W + \Delta U$

$\therefore \Delta U = 2046.5 - 191.32$

$= 1855.2$ KJ/kg

From steam table

$\Delta S = S_g - S_f$

$= 4.6139$ KJ/kg

$\therefore \Delta U = 1855.5$ KJ/kg

Soln 12.8

$t_1 = 179.55°C$; $V_1 = 0.01\ m^3$

$v_1 = 0.11274 + 0.95(0.19430 - 0.01274)$

$v_1 = 0.18464\ m^3/kg$

$\therefore mass = \frac{V_1}{v_1} = 0.054$ kg

$V = \frac{0.01\times10^6}{2\times10^5} = 0.05\ m^3$

$v_2 = (0.05)/(2\times10^5)$

$v = \frac{0.05}{0.054} = 0.92321\ m^3/kg$

From superheated steam table

V at 2.00 bar at 120.2°C = 0.88540

V at 2.00 bar at 150.0°C = 0.95954

The temp when $V = V_2 = 0.92321$

$= 120.2 + \left(\frac{0.92321 - 0.88540}{0.9584 - 0.88540}\right)(150 - 120.2)$

$= 120.2 + 15.197 = 135.40°C$

(b) $W = P_1V_1 \ln\frac{P_1}{P_2}$

$= 10^6 \times 0.01 \ln\left(\frac{10^6}{2\times10^5}\right)$

$\therefore W = 16.094$ KJ

(c) $S_1 = 2.1382 + 0.95(4.4447)$

$\therefore S_1 = 6.36066$ KJ/kg K

Superheated at 2 bar 120°C = 7.1268

at 150°C; S = 7.2794

at 2 bar at 135.40°C

$S_2 = 7.1268 + \left(\frac{7.2794 - 7.1268}{150 - 120.2}\right)\times(135.40 - 120.2)$

$\therefore S_2 = 7.20463$ KJ/kg

Increase in entropy; $\Delta S = S_2 - S_1$

$\therefore \Delta S = 0.844$ KJ/kg

$\Delta S = 0.844 \times 0.05$ KJ/kg

$\Delta S = 0.0422$ KJ/kg

Superheat h at 2.00 bar (120.2) = 2706.3 KJ/kg

h at 3.00 bar (150°C) = 2768.5 KJ/kg

h at 2.3 bar (135.40°C)

$h_2 = 2706.3 + \left(\frac{2768.5 - 2706.3}{29.8}\right) \times 15.2$

$\therefore h_2 = 2738.03$ KJ/kg

$U_2 = h_2 - pV_2$

$= 2553.38$ KJ/kg

Change in internal energy $\Delta h = 62.58$ KJ/kg

$\Delta U = 62.68 + 0.05 = 3.13$ KJ

From 1st law;

$\Delta Q = \Delta U + \Delta W$

$= 3.13 + 16.09$

$\Delta Q = 19.22$ KJ

Soln 13.13

(a) $t_1 = 191.04$ °C

$V_2 = 0.14073$ m³/kg

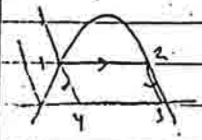
$h_2 = 2187.8$ KJ/kg

$S_2 = 6.4651$ KJ/kg K

$V_1 = 0.0011489$ m³/kg

$h_1 = 830.1$ KJ/kg

$S_1 = 2.2836$ KJ/kg



Now, from S.F.E.E

$\frac{Q - W_x^0}{m} = \Delta\left(h + \frac{v^2}{2}^0 + \frac{gz}{J}^0\right)$

$\Rightarrow \Delta Q = 1957.7$ KJ/kg

$\because W_x = 0$

(ii) Q = 0

$S_2 = S_3 = 6.4651$ KJ/kg

$6.4651 = 1.3027 + x(6.6571)$

$\therefore x = 0.852$

$h_3 = 417.5 + 0.852 \times 2257.9 = 2341.9$ KJ/kg

$\therefore -\frac{W_x}{m} = -445.9$

$\therefore W_x = 445.9$ KJ/kg

(iii) $t_4 = 99.63$

$S_1 = S_4 = 2.2836$ KJ/kg K

$\therefore 2.2836 = 1.3027 + x(6.0571)$

$\therefore x = 0.167$

$h_4 = 417.5 + 0.162 \times 2257.9$

$\therefore h_4 = 783.15$ KJ/kg

$\frac{Q - W_x^0}{m} = \Delta h$

$\therefore Q = -1558.75$ KJ/kg

(iv) Heat transfer (Q) = 0

$-\frac{W_x}{m} = h_1 - h_4$

$= 880.1 - 783.15$

$\therefore W_x = -47$ KJ/kg

(b) $\Sigma W_x = 445.9 - 47$

$= 398.9$ KJ/kg

$\Sigma Q = 1957.7 - 1558.75$

$= 398.95$ KJ/kg

(c) $\eta_{cycle} = \frac{398.9}{1957.7} = 20.4\%$

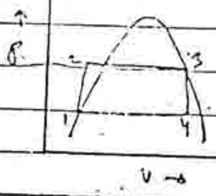
13.14

Saturated steam at 1500 kN/m²

$h_1 = h_{f_1} = 417.5$ KJ/kg

$S_1 = S_{f_1} = 1.3027$ KJ/kg

$V = v_{f_1} = 0.0010434\ m^3/kg$



pump work

$W_{p_1} = V \cdot (P_2 - P_1)$

$= 0.0010434(1.4\times10^{-3} - 64\times10^{2})$ KJ

$= 1.356$ KJ

This work is ignored for process $1\to2$; $Q=0; W=0$

$W_{3\to4} = W_{2\to3} = 445.9$ KJ/kg

For process 2-3

$h_2 = h_1 = h_{f_1} = 417.5$ KJ/kg

$h_3 = 2787.8$ KJ/kg

$\therefore$ Heat transfer $= h_3 - h_2 = 2370.3$ KJ/kg

work done $= 0$.

Process $2\to3$; $Q = 2370.3$ KJ

$W = 0$

Process $3\to4$

Work is equal to expansion work from above i.e. $W_{2\to3}$

$\therefore W = 443.9$ KJ/kg ; $Q = 0$

Process $4\to1$

$h_4 = 2341.9$ KJ/kg

$h_1 = 417.5$ KJ/kg

$\therefore$ heat transfer $= -(h_4 - h_1)$

$= -1924.4$ KJ/kg

Work done $= 0$

$= 445.9$ KJ/kg

(c) $q_u = q_{2-3}$

$\eta = \frac{W_{net}}{q_u} = \frac{449.5}{2370.3} \times 100 = 18.8\%$

Ans 13.15

(a) $\Delta\left[\frac{V^2}{2g_c} + \frac{gz}{g_c}\right] + W_x = -\int v\,dP$

$\therefore W_x = -\int v\,dP$

If final and initial pressure are P_2 & P_1 respectively

then $W_x = -V(P_2 - P_1)$

$\therefore W_x = V(P_1 - P_2)$

(b) $W_x = \frac{0.001007\,(7-3)\times10^6}{10^3}$

$\therefore W_x = 3.02$ KJ/kg.

Ans 13.16

(a) $S_1 = 6.7471$

Flow is adiabatic

$\therefore S_1 = S_2$

$6.7471 = s_f + x\,s_{fg}$

$\therefore x = 0.802$

$W_x = h_2 - h_1$

$\therefore h_1 = 3117.5$

$h_2 = 163.4 + 0.802(2409.2)$

$h_2 = 2095.105$

$W = 1022.4$

HEAT TRANSFER..

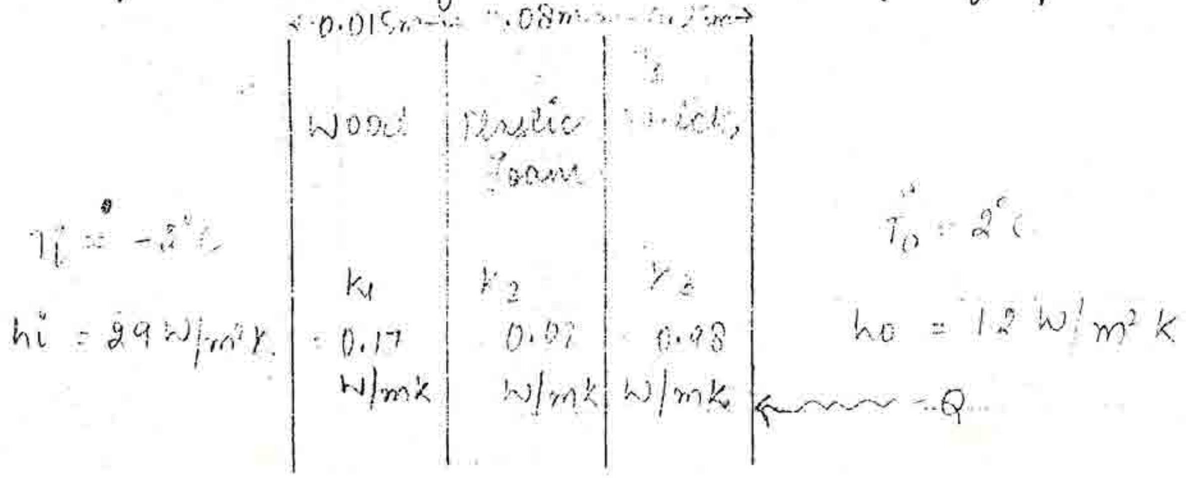
Q1. A cold storage room has walls made of 0.23 m of brick on outside, 0.08 m of plastic foam, and finally 1.5 cm of wood on the inside. The outside and inside air temperatures are 22°C and −2°C respectively. If the inside and outside heat transfer coefficients are respectively 29 and 12 W/m²K and thermal conductivity of brick, foam and wood are 0.98, 0.02 and 0.17 W/mK. Determine:

a) The rate of heat removed by refrigeration if the local area is 90 m².

b) The temperature of inside surface of the brick.

Sol^n: Area = 90 m²

Let Q be rate of heat removal by refrigeration



Q = convection + conduction

$$Q = \frac{T_B - T_A}{\left(\frac{1}{h_i A}\right) + \frac{1}{(h_o A)} + \left(\frac{b_1}{K_1 A}\right) + \left(\frac{b_2}{K_2 A}\right) + \left(\frac{b_3}{K_3 A}\right)}$$

$$Q = \frac{(22+2) \times 90}{\left(\frac{1}{29}\right) + \left(\frac{1}{12}\right) + \left(\frac{0.015}{0.17}\right) + \left(\frac{0.08}{0.02}\right) + \left(\frac{0.23}{0.98}\right)}$$

$$\boxed{Q = 486.4 \text{ W}}$$

Let the rate of heat transfer through brick be Q_1.

$Q = Q_1$ = (Conduction + Convection) through brick.

$$486.4 = \frac{(22 - T_1)\,^\circ C}{\left(\frac{0.23}{0.98 \times 90}\right)} + \frac{(22 - T_1)}{\left(\frac{1}{12 \times 90}\right)}$$

$$T_1 = 22^\circ - \frac{486.4}{90}\left[\left\{\frac{0.23}{0.98}\right\} + \left\{\frac{1}{12}\right\}\right]$$

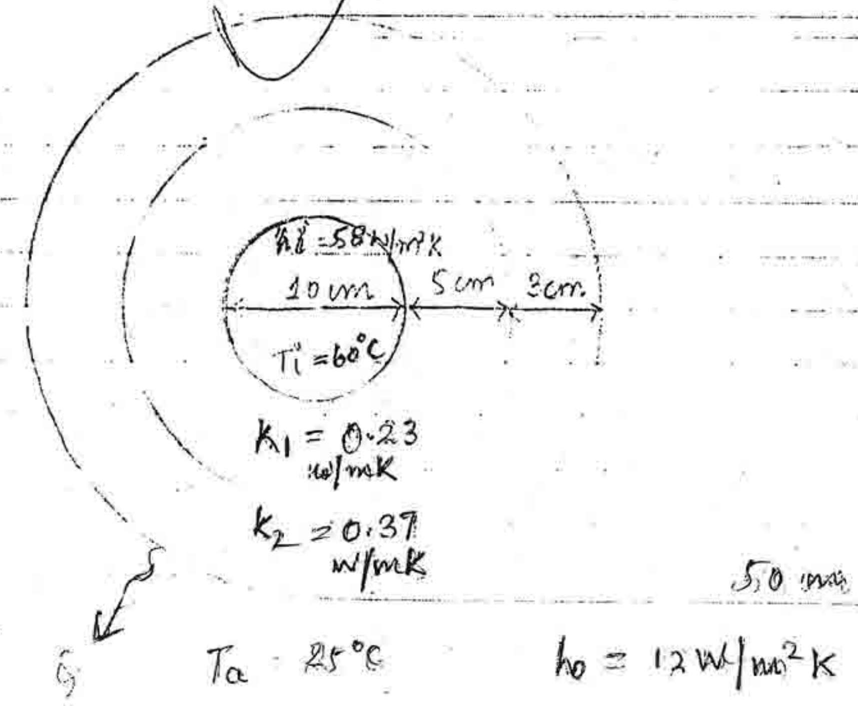
$$= 22^\circ C - 1.718^\circ C$$

$$\boxed{T_1 = 20.28^\circ C}$$

Inside Temp. of brick

Q2. Hot Air at a temperature of 60°C is flowing through a steel pipe of 10 cm diameter. The pipe is covered with two layers of different insulating materials of thickness 5 cm and 3 cm; their corresponding thermal conductivities are 0.23 and 0.37 W/mK. The inside and outside heat transfer coefficients are 58 and 12 W/m² K. The atmosphere is at 25°C. Find rate of heat loss from a 50 m length of pipe, neglecting resistance of steel pipe.

Solⁿ: Length of pipe = 50 m
Diameter of pipe = 10 cm = 0.1 m
Thermal conductivities of two insulating materials,
$k_1 = 0.23$ W/mK
$K_2 = 0.37$ W/mK



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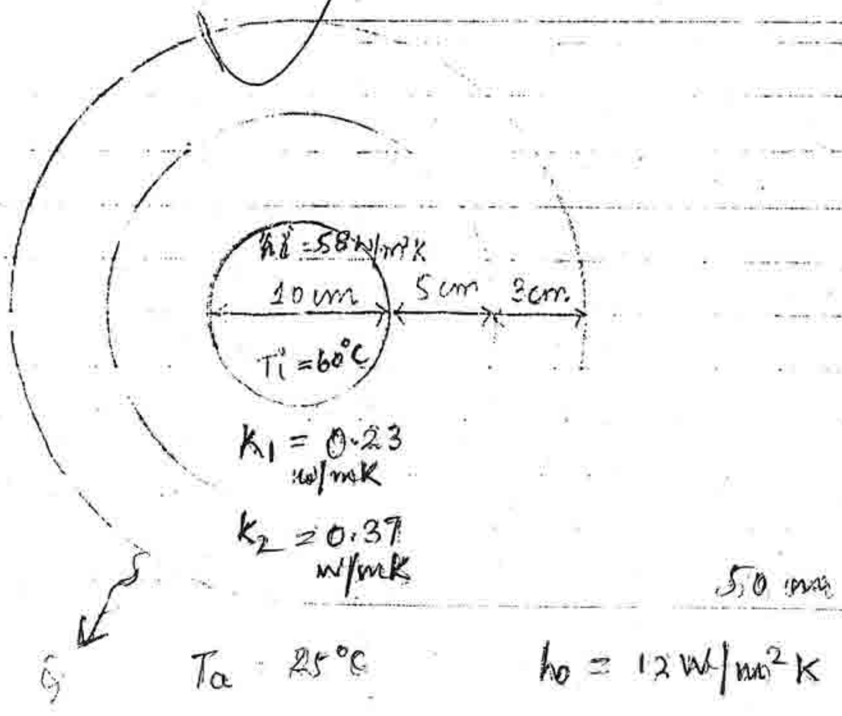


Rate of heat loss, $Q = \dfrac{(60-25)}{\left(\frac{1}{h_i A_i}\right)+\left(\frac{1}{h_o A_o}\right)+\frac{\ln\left(\frac{10}{5}\right)}{k_1 A_1}+\frac{\ln\left(\frac{13}{5}\right)}{K_2 A_2}}$

$$Q = \frac{(60-25)}{\left(\frac{1}{58\times 2\pi(5\times10^{-2})\times 50}\right)+\left(\frac{1}{12\times 2\pi\times 50\times 13\times 10^{-2}}\right)+\left(\frac{\ln 2}{0.23\times 2\pi\times 50}\right)+\left(\frac{\ln(1.3)}{0.37\times 2\pi\times 50}\right)}$$

$$Q = \frac{35\times 2\pi\times 50}{\frac{1}{58\times 5\times 10^{-2}}+\frac{1}{12\times 13\times 10^{-2}}+\frac{\ln 2}{0.23}+\frac{\ln(1.3)}{0.37}}$$

$$Q = \frac{10995.58}{0.345+0.641+0.709+3.01}$$

$$Q = \frac{10995.58}{4.705}$$

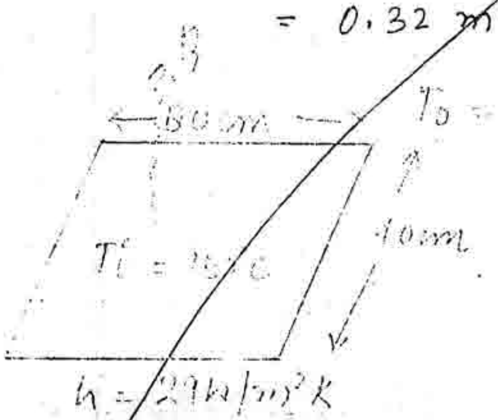
$$\boxed{Q = 2.335\ \text{KW.}}$$

Q3. Air at 15°C flows over a hot plate of area 40×80 cm^2, which is maintained at 150°C, The heat transfer coefficient is 29 W/m^2K.
Determine the heat transfer rate.

sol^n: Area of plate $= 40 \times 80\ cm^2$

$= 3200\ cm^2$

$= 0.32\ m^2$



Heat transfer Rate, $Q = hA\,(T_i - T_o)$

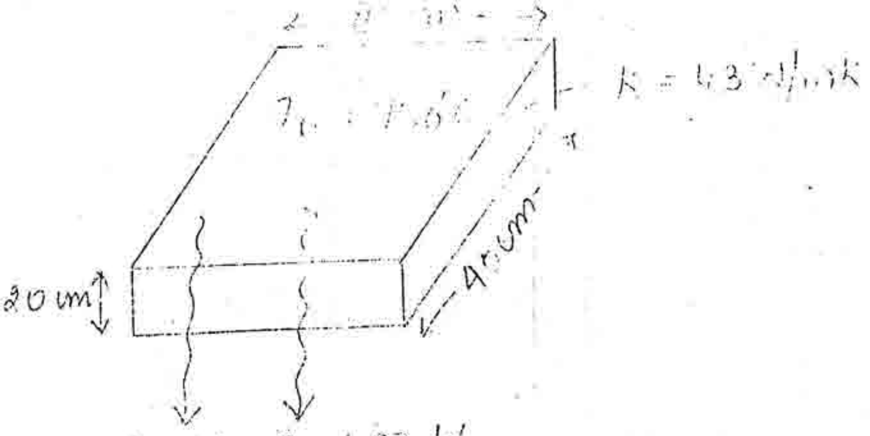
$Q = 29 \times 0.32 \times (150°C - 15°C)$

$Q = 1252.8\ W$

$\boxed{Q = 1.253\ KW}$

Q4. If the plate in the above problem is made of steel ($K = 43 \, W/mK$) and having thickness 20 cm and that 582 W is lost from the plate surface by radiation, determine the inside temperature of the plate.

Sol^n:



Heat loss through radiation, $Q_r = 582 \, W$
Heat loss through convection, $Q_c = 1252.8 \, W$

→ Since, the plate is made of steel and heat flows inside steel by conduction. Heat loss by conduction must be equal to net loss to the surroundings as there is no loss of heat

$\therefore$

$$Q_{conduction} = Q_c + Q_r$$

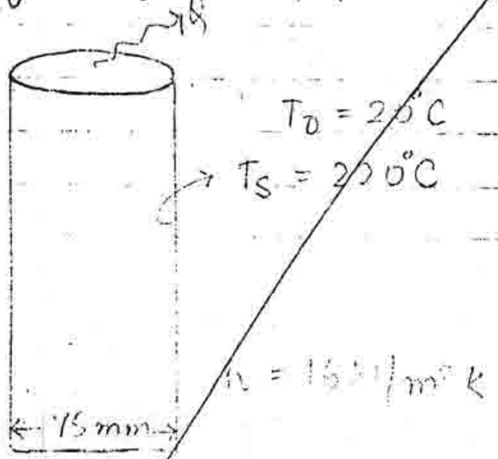
$$\frac{T_i - 150}{\left(\frac{0.2}{0.32 \times 43}\right)} = 1252.8 + 582$$

$$T_i = \left(1834.8 \times \frac{0.2}{0.32 \times 43} + 150^\circ C\right)^\circ C$$

$$\Rightarrow \boxed{T_i = 176.66^\circ C}$$

Q5. An insulated steam pipe of diameter 75 mm is laid down in a room in which the air and walls are at a temp. of 20°C. The surface temp. and emissivity are 220°C and 0.85 respectively. Calculate the rate of heat transfer from surface per unit length of the pipe if $h = 16\ W/m^2K$.

Sol^n:



Rate of heat transfer Q = $\underbrace{\text{heat trans. through convection}}_{Q_c}$ + $\underbrace{\text{through radiation}}_{Q_r}$

$$Q_r = \frac{e\sigma A}{L}(T_s^4 - T_0^4) = \text{radiation per unit length.}$$

$$Q_r = 0.85 \times 5.66 \times 10^{-8} \times 2\pi\left(\frac{75}{2}\times 10^{-3}\right)(220^4 - 20^4)$$

$\therefore\ Q_r = 26.55\ W$.

$$Q_c = \text{convection per unit length} = \frac{T_s - T_0}{\frac{1}{\frac{hA}{L}}}$$

$$Q_c = (220-20)(16)(2\pi)\left(\frac{75}{2} \times 10^{-3}\right)$$

$$= 753.98 \text{ W}$$

$$\Rightarrow \quad Q = Q_c + Q_r$$

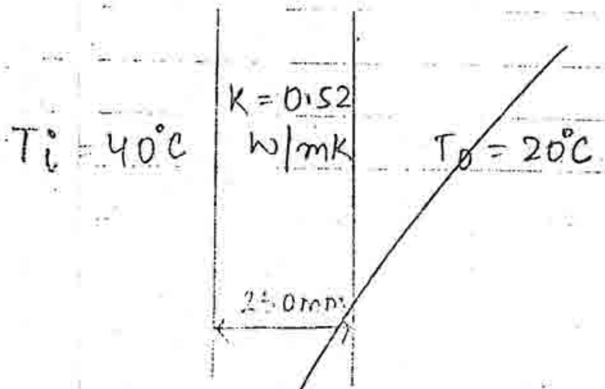
$$= 753.98 + 26.55$$

$$\boxed{Q = 780.53 \text{ W}}$$

Q6. The inner surface of a brick wall is at 40°C and the outer surface is at 20°C. Calculate the rate of heat transfer per square metre of surface area of the wall, which is 250 mm thick.

$K_{brick} = 0.52\ W/mK$.

Sol^n:



Let the area of brick wall be A.

Rate of heat transfer, $Q = \dfrac{Ti - To}{\dfrac{L}{KA}}$

$\Rightarrow$ Rate per unit area $= \dfrac{Q}{A}$

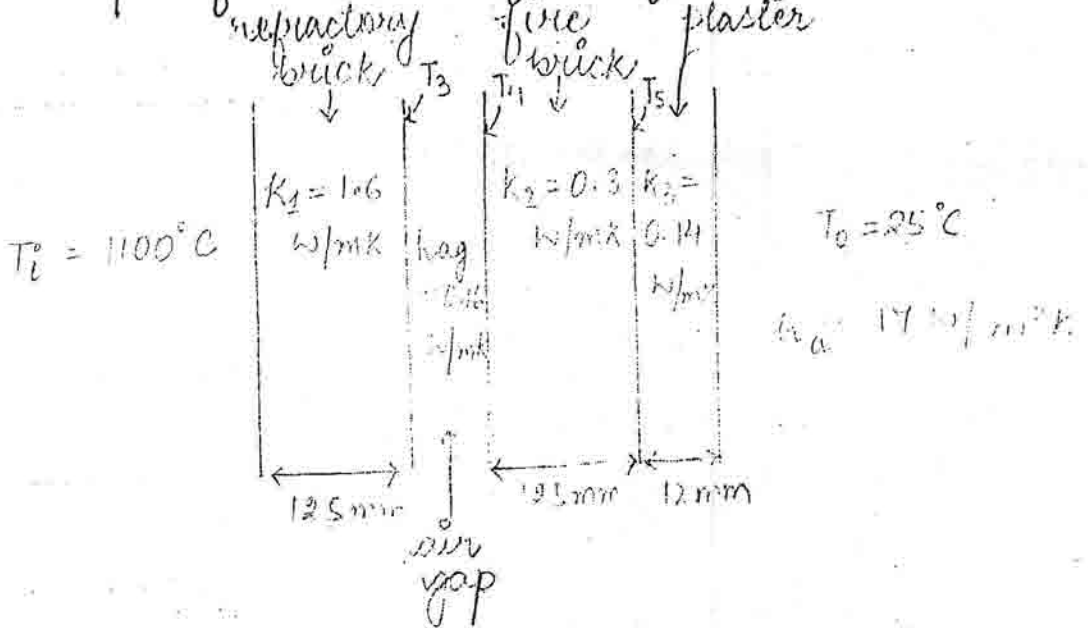
$$\frac{Q}{A} = \frac{Ti - To}{\dfrac{L}{K}} = \frac{(Ti - To)K}{L}$$

$$\frac{Q}{A} = \frac{0.52(40-20)}{250 \times 10^{-3}}$$

$$\boxed{\frac{Q}{A} = 41.6\ W}$$

Q7. A furnance wall consists of 125 mm wide refractory brick and 125 mm wide insulating fire brick separated by an air gap. The outside wall is covered with a 12 mm thickness of plaster. The inner surface of the wall is at 1100°C and the room temp. 25°C. Calculate the rate at which heat is lost per m^2 of wall surface. The heat transfer coefficient from the outside wall surface to the air in the room is 17 W/m^2K and resistance to heat flow of the air gap is 0.16 K/W. The thermal conductivity of refractory brick, firebrick wall and plaster are 1.6, 0.3 and 0.14 respectively. Calculate also, each interface temp. and the temp. of outside surface of the wall.

Solⁿ:



$$\text{Heat transfer / area}, \; Q = \frac{T_i - T_0}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} + \frac{1}{h} + 0.1}$$

$$Q = \frac{1100 - 25}{\left(\frac{125 \times 10^{-3}}{1.6}\right) + \left(\frac{125 \times 10^{-3}}{0.3}\right) + \left(\frac{12 \times 10^{-3}}{0.14}\right) + \left(\frac{1}{17}\right) + 0.16}$$

$$Q = 1344.877 \text{ W}$$

$$\boxed{Q = 1.344 \text{ KW}}$$

Let heat transfer rate/area through ref. brick, fire brick and plaster be Q_1, Q_2, Q_3.

Then, $Q = Q_1 = Q_2 = Q_3$.

$$Q_1 = \frac{(1100 - T_3) \times 1.6}{125 \times 10^{-3}} = 1344.877$$

$$T_3 = 994.93 \approx \boxed{995^\circ C = T_3}$$

$$Q_2 = \frac{(T_4 - 219.38) \times 0.3}{125 \times 10^{-3}} = 1344.877$$

$$T_4 = 779.74 \approx \boxed{780^\circ C = T_4}$$

$$Q_3 = \frac{(T_5 - 25)}{\frac{12 \times 10^{-3}}{0.14} + \frac{1}{17}} = 1344.877$$

$$T_5 = 219.38 \approx \boxed{220^\circ C = T_5}$$

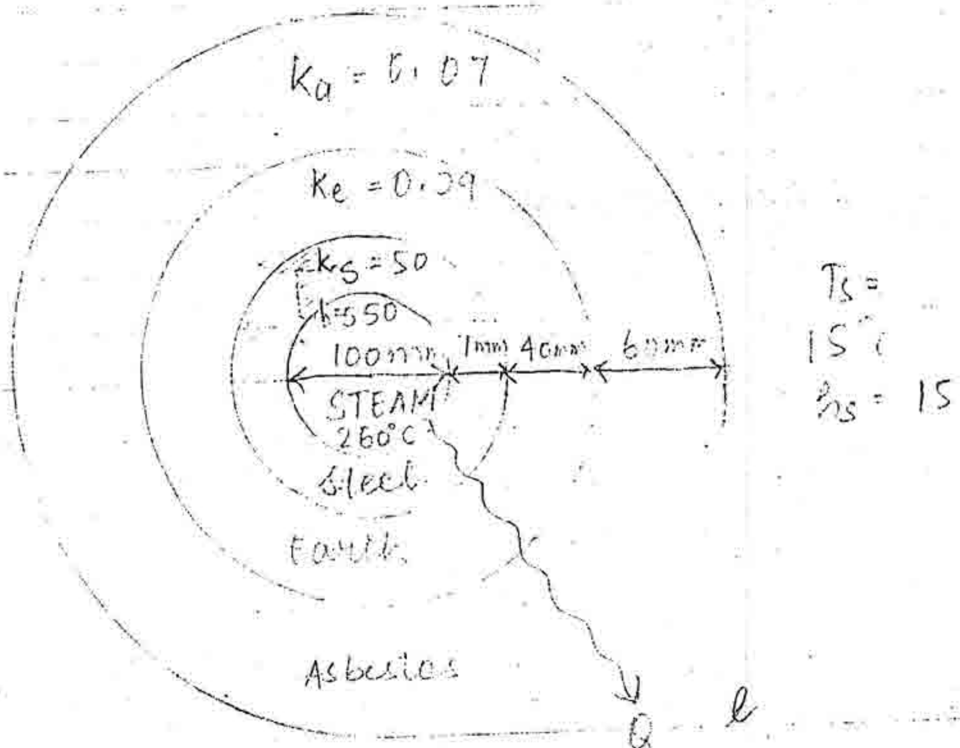
Temp. of outside surface of wall, T :

$$Q = \frac{T - 25}{\frac{1}{17}} = 1344.877$$

$$\Rightarrow \boxed{T = 104^\circ C}$$

Q8. A steel pipe of 100 mm bore and 7mm wall thickness, carrying steam at 260°C is insulated with 40mm earth covering. This covering is in turn insulated with 60 mm of asbestos felt. If the atmospheric temp. is 15°C, calculate the rate at which heat is lost by steam per m length of pipe. The heat transfer coeff. for inside and outside surface are 550 and 15 W/m²K and thermal conductivity of steam, earth and asbestos felt are 50, 0.09 and 0.07 W/mK resp. Calculate also the temperature of outside surface.

Sol^n:



$$Q = \frac{T_i - T_s}{\left[\frac{1}{hA_1} + \frac{1}{h_s A_2} + \frac{\ln(r_2/r_1)}{2\pi k_1 l_1} + \frac{\ln(r_3/r_2)}{2\pi k_2 l_2} + \frac{\ln(r_4/r_3)}{2\pi k_3 l_3}\right.}$$

Q per unit length, $Q' = \frac{Q}{L}$

$$\Rightarrow Q' = \frac{260-15}{\left[\left(\frac{1}{550\times 50\times 10^{-3}\times 2\pi}\right)+\left(\frac{1}{15\times 157\times 10^{-3}\times 2\pi}\right)+\frac{\ln\left(\frac{57}{50}\right)}{2\times\pi\times 50}+\frac{\ln\left(\frac{97}{57}\right)}{2\pi(0.09)}+\frac{\ln\left(\frac{157}{97}\right)}{2\pi(0.07)}\right]}$$

$$Q' = \frac{245}{5.8\times 10^{-3}+0.067+0.417\times 10^{-3}+0.94+1.094}$$

$$Q' = \frac{245}{2.11}$$

$$\boxed{Q' = 116\ W}$$

Let the outside surface temp. be T.

$$Q' \Rightarrow \frac{T-15}{\left(\frac{1}{15}\right)} = 116.$$

$$\Rightarrow T-15 = \frac{116}{15} = 7.8$$

$$\Rightarrow \boxed{T = 22.8^{\circ}C}$$

Q9. A body at 1100°C in black surrounding at 550°C has an emissivity of 0.7 at 550°C.
Calculate rate of heat loss by radiation per m^2:

(a) When body is assumed to be grey with $e = 0.4$.

Soln:

$$\text{Rate of radiation} = e \sigma A (T_2^4 - T_1^4).$$

$$\text{Radiation per } m^2, Q_g = \frac{R}{A} = e\sigma (T_2^4 - T_1^4).$$

$$= 5.67 \times 10^{-8} \times 0.4 \times (1373^4 - 823^4)$$

$$\boxed{Q_g = 70.22 \text{ KW}}$$

(b) When body is not grey.
assume e is independent of surface temp.

$$Q_1 = e \rho A T_1^4$$

$$\frac{Q_1}{A} = e \rho T_1^4$$

$$= 0.4 \times 5.67 \times 10^{-8} \times (1373)^4$$

$$= 8.06 \times 10^{12} \times 10^{-8} = 8.06 \times 10^4$$

$$Q_2 = e\rho A T_2^4$$

$$\frac{Q_2}{A} = e\rho T_2^4$$

$$= 0.7 \times 5.67 \times 10^{-8} \times (823)^4$$

$$= 1.82 \times 10^4$$

$$\therefore \text{Net } Q = \frac{Q_1}{A} - \frac{Q_2}{A}$$

$$= (8.06 - 1.82) \times 10^4$$

$$= 6.242 \times 10^4$$

$$\boxed{Q = 62.42 \text{ KW}}$$